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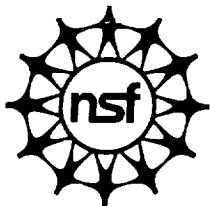
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# JTEC

*JTEC Panel Report on*

## High Definition Systems In Japan

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**February 1991**

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## JAPANESE TECHNOLOGY EVALUATION CENTER

- SPONSOR** The Japanese Technology Evaluation Center (JTEC) is operated for the Federal Government by Loyola College to provide assessments of Japanese research and development (R&D) in selected technologies. The National Science Foundation (NSF) is the lead support agency. Other sponsors include the Defense Advanced Research Projects Agency (DARPA), the National Aeronautics and Space Administration (NASA), the Department of Commerce (DOC), and the Department of Energy (DOE).
- PURPOSE** The JTEC assessments contribute to more balanced technology transfer between Japan and the United States. The Japanese excel at acquisition and perfection of foreign technologies, but the U.S. has relatively little experience with this process. As the Japanese become leaders in research in targeted technologies, it is essential that the United States have access to the results. JTEC provides the essential first step in this process by alerting U.S. researchers to Japanese accomplishments. The JTEC findings can also be helpful in formulating Governmental research and trade policies.
- APPROACH** The assessments are performed by panels of about six U.S. technical experts in each area. Panel members are leading authorities in the field, technically active, and knowledgeable about Japanese and U.S. research programs. Each panelist spends about one month of effort reviewing literature, making assessments, and writing reports on a part-time basis over a nine-month period. Most panels conduct extensive tours of Japanese laboratories. To balance perspectives, panelists are selected from industry, academia, and government.
- ASSESSMENTS** The focus of the assessments is on the status and long-term direction of Japanese R&D efforts relative to those in the United States. Other important aspects include the evolution of the technology, key Japanese researchers and R&D organizations, and funding sources. The time frame of the R&D forecasts is up to ten years, corresponding to future industrial applications in 5 to 20 years.
- LITERATURE** Loyola College provides Japanese literature and translation services to the panelists. Special efforts are made to provide panelists with timely source material, such as informal proceedings from seminars and conferences in the Japanese research community, results from recent technical committee meetings on Japanese national R&D projects, and contacts at R&D centers in Japanese high technology industries.
- REPORTS** The panel findings are presented to small workshops where invited participants critique the preliminary results. The panel final reports are distributed by the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161. The panelists also present the technical findings in papers and books. All results are unclassified and public.
- STAFF** The Loyola College JTEC staff members help select topics to be assessed, recruit experts as panelists, organize and coordinate panel activities, provide literature support, organize tours of Japanese labs, assist in the preparation of workshop presentations and reports, and provide general administrative support. Dr. Alan Engel and Ms. Kaori Niida of International Science and Technology Associates provided literature support and advance work for the panel.

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## **JTEC PANEL REPORT ON HIGH DEFINITION SYSTEMS IN JAPAN**

### **Abstract**

The successful implementation of a strategy to produce high-definition systems within the Japanese economy will favorably affect the fundamental competitiveness of Japan relative to the rest of the world. The development of an infrastructure necessary to support high-definition products and systems in that country involves major commitments of engineering resources, plants and equipment, educational programs and funding. The results of these efforts appear to affect virtually every aspect of the Japanese industrial complex. The present report represents the results of assessments of the current progress of Japan toward the development of high-definition products and systems. The assessments are based on the findings of a panel of U.S. experts made up of individuals from U.S. academia and industry, and derived from a study of the Japanese literature combined with visits to the primary relevant industrial laboratories and development agencies in Japan. Specific coverage includes an evaluation of progress in R&D for high-definition signal processing in Japan; high-definition television (HDTV) displays that are evolving in Japan; high-definition standards and equipment development; Japanese intentions for the use of HDTV; economic evaluation of Japan's public policy initiatives in support of high-definition systems; management analysis of Japan's strategy of leverage with respect to high-definition products and systems.

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JTEC Panel on

# **HIGH DEFINITION SYSTEMS IN JAPAN**

## **FINAL REPORT**

February, 1991

Richard J. Elkus, Jr., Chairman  
Robert B. Cohen  
Birney D. Dayton  
David G. Messerschmitt  
William F. Schreiber  
Lawrence E. Tannas, Jr.

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## PREFACE

The JTEC Panel on High Definition Systems was established under the auspices of the National Science Foundation. The purpose of the Panel was to assess current progress in Japan toward the development of high definition products and systems. It was not the function of the Panel to make any recommendations as to what actions the United States should take as a result of the analysis.

During the course of the Panel's investigations, it became clear that the development of an infrastructure necessary to support high definition products and systems in Japan involves major commitments of engineering resources, plant and equipment, education programs, and, of course, money. The results of these efforts appear to affect virtually every aspect of the Japanese industrial complex.

The successful implementation of a strategy to produce high definition systems within the Japanese economy will favorably affect the fundamental competitiveness of that society relative to the rest of the world. How the United States or others should react must be a part of a different study. Let it suffice to say that the impact of Japanese efforts in these areas should not be ignored by any society wishing to remain competitive in world markets, particularly as they relate to electronics, telecommunications, and the media.

The Panel is indebted to the National Science Foundation for its support and encouragement. The Panel also appreciates the many organizations within Japan, including their management and key personnel who so willingly helped us in our effort to more fully understand the Japanese concept of high definition systems. Specifically, on behalf of the JTEC Panel on High Definition Systems, I would like to thank the Japanese organizations (listed in Appendix B) who were our gracious hosts during the Panel's visit to Japan in 1989.

In addition, the Panel would like to express its sincere appreciation to the following individuals who worked diligently and very closely with the members of the Panel in preparing materials, developing schedules, establishing meetings, and arranging important contacts during our visit to Japan: The JTEC staff (Duane Shelton, Geoff Holdridge, Bob Williams, Pat Johnson, Aminah Batta, and the Loyola College student research assistants), and ISTA, Inc. (Alan Engel and Kaori Niida).

Though the actual time spent by the Panel in Japan as a group was approximately one week, each of the members of the Panel spent considerable time in Japan prior to and subsequent to that trip on matters directly pertaining to the subject at hand. So, in reality, the list of credits should be much greater than those noted above. Let it suffice to say that each one of us found the cooperation of our Japanese hosts immensely valuable in our effort to broaden our understanding of the relationship between our two countries as it pertains to high definition systems.

Richard J. Elkus, Jr.  
Prometrix Corporation

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## EXECUTIVE SUMMARY

D.G. Messerschmitt evaluates the progress in R&D for high definition signal processing in Japan in Chapter 1. This review finds that digital signal processing should be regarded as a technology driver because of the high sampling rates required for high resolution video applications, like HDTV. It also indicates that related applications in computer and information systems will depend on advances in digital signal processing for HDTV. Messerschmitt provides details of the R&D in Japan for advanced broadcast television, concentrating on reviews of the work on signal processing, transmission media, and receiver types. He concludes that the video developments in Japan will be a significant technology driver for other technologies, especially high performance computing, semiconductor technologies and electronic video technologies.

In Chapter 2, L.E. Tannas examines HDTV displays that are evolving in Japan. He evaluates the R&D environment for advanced televisions and the work that has been done on high definition television displays. This review describes efforts being made in Japan on cathode ray tube (CRT) technologies for HDTV, active matrix liquid crystal projectors, new screen technologies for projection displays and flat panel displays. Tannas finds that the large flat-panel, direct view display is likely to be unavailable until the year 2000. But he also indicates that there have been significant improvements in CRT technology, in high performance projection lenses optimally coupled to the CRT, and in projector screens, particularly rear projection screens, that permit CRT projectors to challenge the best classical industrial electronics projectors.

High definition standards and equipment development in Japan are reviewed in Chapter 3, by B.D. Dayton. This chapter examines the similarities and differences between the process of developing standards in the U.S. and in Japan. It provides specific details of production standards for video interfaces and tape recording formats and of industrial standards for tape recorders. It then discusses recent work on a digital HDTV recorder using digital image compression techniques and on EDTV equipment operating at 525/59.94 progressive scan rates and producing both 4:3 and 16:9 aspect ratios. Standards setting for components, such as HDTV semiconductors and displays, and for end use products, such as studio HDTV equipment, industrial products and consumer products, is also considered.

In his essay on Japanese High-Definition Television Systems in Chapter 4, W.F. Schreiber evaluates Japanese intentions for the use of their system in Japan and elsewhere. Schreiber discusses the history of Japanese developments, the NHK wideband "studio" system, the MUSE compression/transmission system, and systems that have been designed for U.S. broadcast use. Because the Japanese MUSE system was designed for direct broadcast satellites use, the author finds that it is suitable only for this original application, even in its MUSE-E version, because it relies on interlaced signals produced by the "studio" system. The MUSE system itself is also found to be characterized by weaknesses related to its failure to use frame stores and the consequent employment of interlace.

In Chapter 5, R.B. Cohen provides an economic evaluation of Japan's public policy initiatives in support of high definition systems. He estimates that Japanese support for high definition efforts from 1964 to 1989 has totalled \$638 million and that ongoing and planned initiatives of various types, including loans, investments, and leasing, will total over \$1.5 billion by 1997. His discussion of Japanese programs highlights the central role that is being played by the Key Technology Center in recent government-backed initiatives, but also reviews planned efforts by the Ministry of International Trade and Industry and the Ministry of Posts and Telecommunications. Cohen emphasizes that the Japanese government programs recognize the need for government efforts to support the success of the early commercialization of HDTV, particularly through the development of industrial applications. He indicates that these applications will have a crucial role in shaping the future development of Japan's electronics industry, especially the next generation of computer and communications systems.

Finally, in the Management Analysis, R.J. Elkus makes several interesting observations. According to Elkus, high definition products and systems are designed to process substantially increased amounts of audio-visual information. The effect of high definition systems is to push products within the media, telecommunications and electronics markets to a higher state of development. The creation of high definition products and systems within the Japanese electronic industry is in part the result of a fundamental strategy that assumes products and markets become more and more inter-related during the course of development.

The inter-relationship of strategic products and markets create an infrastructure that becomes very difficult to penetrate by competitors who lack a position of strength within that infrastructure. The power of an integrated infrastructure of end-use products and markets will begin to dominate technological development, intellectual property rights, and component development--not the other way around.

Ensuring a fundamental position in the markets of media, telecommunications and electronics with the development of high definition products and systems should provide Japan with a strong position in all other related markets including supporting technology and component development. The result may be a preeminent position for Japan in the coming "information society" age.



## **CHAPTER 1**

# **INTRODUCTION TO HDTV AND ITS SIGNAL PROCESSING**

David G. Messerschmitt

### **INTRODUCTION**

The primary purpose of this chapter is to introduce Japanese research and development activities in high definition systems (particularly HDTV), including the video/image signal processing where most of the electronic issues reside. These activities should be viewed, however, in the larger context of video and image processing products and services, especially those requiring high-resolution images. Developments in HDTV signal processing are resulting in new technology directly applicable to a number of other markets, particularly in the information and computer industries. As a result, research and development in the signal processing circuitry of HDTV systems has a significance that transcends the particular current products that they address.

The broader significance of HDTV development in Japan is evident in the case of the improvements made in digital signal processing (DSP) capabilities for HDTV transmitters and receivers, which squarely impact the general purpose computer market. Furthermore, the Japanese government and electronics industries are acutely aware of the broader market implications of HDTV research and development. Increasingly refined concepts of the "New Age" and "New Media" and the "Information Society" of the future are commonly described in government and industrial publications in Japan. Figuring prominently in these concepts are numerous high definition image products and services, spanning the fields of medicine, manufacturing, publishing, film-making, telecommunications, education, and a host of others.

HDTV is simply one component of a much more encompassing marketplace; one that includes the computer and information industries in which the U.S. is currently dominant. Therefore, as R&D activities continue apace in signal processing and other high definition image technologies specifically for television, it is becoming increasingly apparent that the Japanese companies engaged in these activities will be well positioned in a number of evolving interrelated markets, and will challenge U.S. dominance of the computer and information marketplace.

### THE SIGNIFICANCE OF IMAGE AND VIDEO SIGNAL PROCESSING AS A TECHNOLOGY DRIVER

Regardless of whether a high definition video signal is transmitted by direct-broadcast satellite in Japan or Europe, or by terrestrial broadcast or fiber optics in the U.S., the basic technology used to implement the transmitter and receiver functions is digital signal processing (DSP). The basic idea behind DSP is illustrated in Figure 1.1, where an analog signal is sampled, digitized using an analog-to-digital converter (A/D), and some processing or computation is performed in the digital domain. We can define DSP as real-time computation on a sampled and quantized signal (audio, video, radar, sonar, seismic, etc.) for the purpose of compression, enhancement, also error correction, encryptions/decryption, calibration/correction, or information extraction.

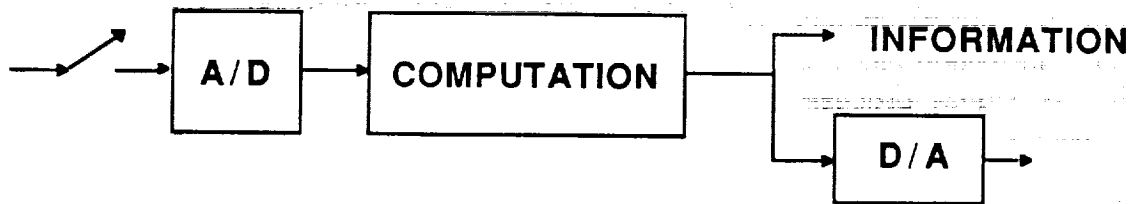


Figure 1.1. Basic Idea Behind Digital Signal Processing (DSP)

The most important applications of DSP are in consumer products (audio and video systems), in computer systems (image information storage and retrieval, speech recognition and response), and in military equipment (sonar and radar) and automatic control. However, the true importance of DSP transcends these direct applications; it is an important *electronics technology driver*. A DSP system is basically a specialized computer, dedicated to a particular processing

function. As such, it typically has a very high processing rate compared with general-purpose computers. In fact, processing rates expressed in number of multiplies per second in a DSP system often exceed those of the fastest supercomputers.

The U.S. has heretofore been dominant in markets for specialized DSP processors, called programmable DSPs. Programmable DSPs are very similar to the reduced instruction-set computer (RISC), which has become the most popular microprocessor in the general-purpose computer market. Like RISC, the programmable DSP is simply a microprocessor with a simplified instruction set. While the concepts of programmable DSP and RISC developed independently at about the same time, the programmable DSP arrived in the commercial marketplace about ten years earlier than RISC. This illustrates the technology driver aspect of DSP, due to its requirements for very high processing rates. Because of their focus on DSP in video applications (the highest performance applications among the commercial markets), Japanese companies are gaining a lead in high-performance DSP. This lead can be directly leveraged into a lead in general-purpose computer hardware.

DSP is also important as a technology driver in parallel processing, which is the next major advance in supercomputers. Since the sampling rates for high-resolution video applications like HDTV are very high, particularly compared to typical clock rates for low-cost electronics technologies like CMOS, any significant processing requires parallelism. Japanese companies are gaining invaluable experience in parallel processing through their video signal processing developments. Many parallel processor DSP machines have been developed in Japanese companies as a part of their video development programs. These machines have given them considerable experience in software design for parallel processing, in addition to experience in hardware design. This experience can be applied to the design of parallel processing supercomputers.

## **HDTV AND THE INFORMATION SYSTEMS OF THE FUTURE**

This section will describe the more general view of video and image processing in Japanese organizations. It will highlight actions that indicate that these organizations believe that video and image processing is the key to the information industries of the future.

### **Interrelated Video/Image Products and Markets**

Among the most important applications related to HDTV for high-resolution image-signal processing technologies are computer and information systems.

These have in the past emphasized textual interfaces consisting of words and numbers. More recently, there has been a greater emphasis on graphics interfaces, such as in the windowing systems pioneered by Xerox and Apple. Computer companies around the world anticipate that user interfaces of the future will increasingly use communication media that are more natural to human beings; namely, speech, images, and video (moving images). This is feasible because of rapid advances in speech and video signal processing, as well as the rapidly increasing processor power and memory sizes that can be realized at reasonable cost. As a result, it will be common to pass information and commands to the information system using speech; and to access interactively data bases that contain speech, image, and video information.

In addition to impacting information systems, video and image processing will impact some other important markets. In telecommunications, multimedia user interfaces that allow pictures and video to accompany speech and data will become common. The low-resolution segment of the printing industry has already been displaced by desktop publishing systems and laser printers, the print engines of which are built in Japan. As this technology moves to higher resolutions, it will increasingly displace other conventional printing techniques. In photography, the home movie camera has been displaced by video camcorders (largely from Japan), and both Sony and Canon are beginning to market still cameras which use electronic recording media. Electronic imaging and video will be used more and more heavily for industrial and medical applications such as training, remote monitoring, robotics, manufacturing, and lithography. Finally, imaging is a critical military technology.

### **Components of Future Information Systems**

To emphasize the expected advances in information systems, we can summarize the elements of the system of the future as shown in Figure 1.2 and below:

*The processor, local-area network, and communications interface to the outside world.* These are all areas in which U.S. manufacturers currently are dominant. The European companies are rapidly increasing their strength in the communications aspects.

*The image output, including the display and printer.* Japan already dominates the high-resolution image peripherals market. In the future, displays will also show full-motion video, for example in accessing video databases and in telephone conferencing.

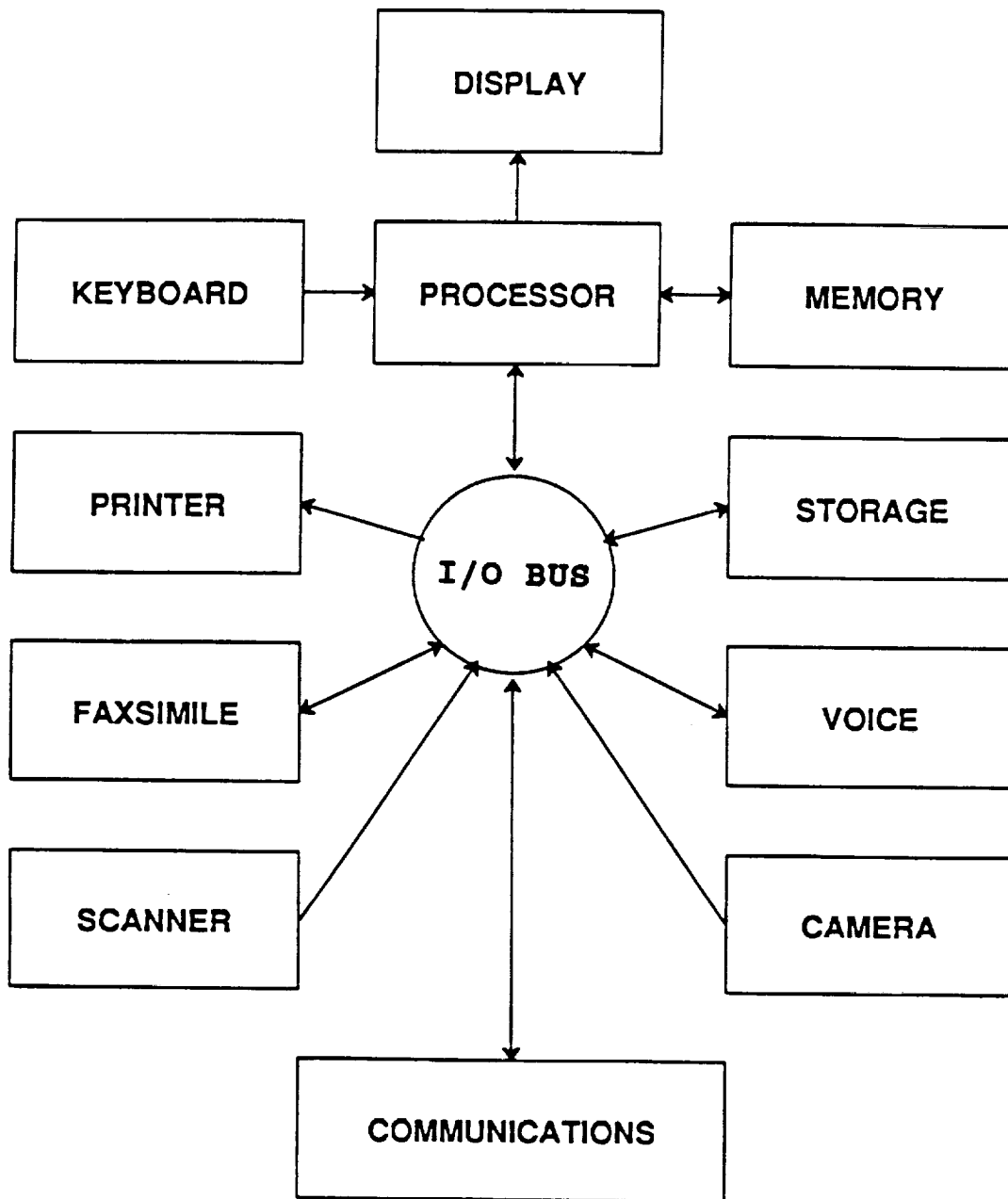


Figure 1.2. Some basic elements of the computer and information system of the future.

*The image input, including scanner (still images) and video camera.* These technologies are dominated by Japanese companies, except for scanners with the highest resolutions, where U.S. companies have competitive products. Speech input and output devices. With the exception of continuous speech recognition, these functions require much lower levels of processing power. U.S. companies are dominant.

*The memory and magnetic and optical storage devices.* These are areas where U.S. and Japanese companies are roughly equivalent. However, Japanese efforts in video are resulting in impressive new technology in these areas. For example, the Sony 1.2 Gb/s digital recorder developed for HDTV (see Chapter 3) is the fastest magnetic recorder in the world, for this application, by a factor of five.

*Image transmission devices.* One example is the facsimile machine, which is essentially a combination of a scanner and printer.

*Software (not shown in Figure 1.2).* This is an important component presently dominated by the U.S. In time, the value of the processing and networking components in information systems is likely to decrease on a percentage basis, while the percentage of added value in the hardware portions--i.e., in the displays, storage devices, scanners, cameras, and printers--will probably increase. The hardware portions are all dominated by Japanese companies. Their HDTV development efforts are an important component in their strategy to strengthen their presence in the information markets of the future.

### **Japan's Commitment to the Emerging Information Industries**

The Japanese manufacturers we visited indicated emphatically that the near-term applications of HDTV technology that would justify their investment were in information systems and industrial applications. This was expressed most strongly by Sony, where the current focus is on industrial applications of HDTV (such as industrial and medical training), as well as on the production of television and entertainment programming. These are immediate applications, whereas the pace of penetration of HDTV broadcast television is less certain.

The long-term focus of Japanese electronic industries on image and video in the information system is made clear from their public relations literature. Cited below are a number of quotes extracted from brochures given to the JTEC team by NHK, NTT, and the major electronics firms we visited in Japan. These extracts are from marketing and public relations material, and are not necessarily backed by real technology investment. Nevertheless, they reveal much about the philosophy and R&D directions of these large Japanese corporations. Throughout these quotes, note the references to "new media,"

"advanced information and vision system," the "intersection of technologies," and the like.

NHK, the quasi-public broadcasting organization that initiated Japan's HDTV efforts, describes its activities to bring about a new information era in these terms:

....the information and communication industries in Japan today are making bold moves to bring various types of New Media into practical use, and are about to undergo a revolutionary transformation to an "era of multi-media."

The objectives are to further improve and diversify broadcasting services in such a way as to make them better fit the conditions in our advanced information-oriented era, and to ensure continuous creation of new "broadcasting culture." (Ref. 1.1)

From NTT, the recently privatized dominant telecommunications company in Japan, here are descriptions of its efforts in the Visual Media Laboratory emphasizing the important role of video and image processing in the telecommunications networks of the future:

....video communication networks, image coding, image storage and retrieval, image processing, three-dimensional (3D) imaging, and imaging devices that explore the advanced technologies that encourage the early establishment of Broadband ISDN and Visual Services.

....enhanced vision systems and sophisticated functions created on a telecommunications network by imaging technology are the two big subjects among all key issues. (Ref. 1.2)

Hitachi Central Research Laboratory describes its efforts in broadcast television work in terms that emphasize the relationship of this work to telecommunications and user interfaces of all types:

To develop "new media" systems, research is conducted on the technology of large-capacity data transmission and intelligent interfaces. Besides optical communication systems...developments are being performed on IDTV and EDTV...and HDTV. (Ref. 1.3)

Statements excerpted from Sharp's literature plainly illustrate how it defines the direction of its efforts in visual image R&D:

Mobilizing technology to build a highly information-intensive society

Marking another milestone in information systems by utilizing existing telephone lines

Creating a new business model that energizes internal communications

Expanding possibilities in TV and video through LCD applications--Sharp's advanced image technology accelerates the pace of information intensity

Caring and sharing real-time visual information around the globe

Leading the way towards the realization of a highly information-intensive society--Sharp continues to set the world's highest standards in application technology. (Ref. 1.4)

Matsushita, the largest consumer electronics company in the world, clearly expects that information systems will be an important part of its future:

#### **The New Media Age--Integrating State-of-the-Art Technologies into Superb Video Equipment**

From extremely compact LCD TVs to large, thin-screen units that hang from a wall, the possibilities in this field are infinite. And beyond this is satellite broadcasting, which uses state-of-the-art electronics technology to make the New Media Age a reality in communication, entertainment, and untold other fields. The TV will continue to be a key part of daily living. The dawning of the New Media Age will find a variety of technologies intersecting, with television the focal point.

The countless application possibilities for LCD TV go well beyond home entertainment. Office machinery using computer display, automobiles, street signs--the possibilities abound.

Satellite Broadcasting...images and data merge in TV screens to create a new age of visual information--one brought to us from the very depths of space.

This final quote from Matsushita is especially revealing in its assertion that HDTV is much more than a broadcast television technology:

High Definition TV Studio--It has been said that HDTV would create an...industry dominated primarily by the TV broadcasting market

principally utilizing home TV receiver units. However, benefiting from the versatility of picture processing technology and by virtue of its capability for excellent color reproduction, HDTV has endless possibilities...including...movies, printing, publishing, medical treatment, and a host of other areas....(Ref. 1.5).

Sony's vision of its future is demonstrated most graphically in its impressive "Media World" exhibit, an entire floor of a building devoted to demonstrating advanced technologies. This exhibit showcases the expected "High Definition Video System," "Professional Video Center," and "Professional Audio Room." But it also contains a number of other demonstrations less clearly related to Sony's current consumer electronics business. These include demonstrations related to information systems, such as the "Information Plaza" and the "Multi-Media Learning Laboratory." Other demonstrations are related to telecommunications, such as the "Teleconference Room," "Video Theater System," and "Picture Communication Area."

Taken as a whole, the literature and exhibits of these major Japanese corporations illustrate their combined vision of and commitment to a "new age" of information technology. Terms like "new media" and "multi-media" are code words for the increasing use of speech, image, and video in all phases of information systems. These "new media" are in fact "old media" in the context of consumer electronics, a field in which the Japanese companies are dominant. But significantly, they are "new media" in the context of the telecommunications, information systems, and computer markets.

## **R&D ACTIVITIES IN JAPAN FOR ADVANCED BROADCAST TELEVISION**

Research in high definition television was begun in earnest in about 1970 by the Japanese public broadcasting organization, NHK. At the time, this was considered a natural extension of NHK's in-house research efforts, and had the general goal of providing superior picture quality in its television broadcasts, thus increasing its number of viewers, expanding its revenues, and bolstering its public support. Signal processing and modulation have been among the primary foci of HDTV research, and substantial progress has been made in these technologies in the intervening twenty years. Signal processing achievements have proven to be applicable not only to HDTV, but also to other television systems and even to other industries (as discussed previously). It should be noted that for the near-term, the most commercially significant uses of HDTV may well be not in broadcasting but in industrial applications.

Before proceeding with the discussion of high definition television R&D activities in Japan, it is appropriate to briefly describe the different television systems that will be discussed in this section.

**NTSC** is the standard television broadcast and reception used in North America and Japan. It requires 6 MHz bandwidth channels for terrestrial broadcast transmission.

**IDTV** (improved definition television) requires no changes to the transmitted signal, but incorporates improved signal processing in the receiver. Typically, the enhancements to the receiver include conversion from interlaced to progressive scan, and cancellation of ghosts introduced by multipath distortion on the transmission channel.

**EDTV** (enhanced definition television) requires changes to both the transmitter modulation and the receiver, but changes in the transmitter are constrained to enable an older NTSC and IDTV receiver to receive and display an acceptable signal (some degradation in picture quality may be acceptable). An EDTV system may or may not use a higher bandwidth than NTSC. Where it uses the same bandwidth, the enhancement signals are inserted into "holes" in the NTSC spectrum. These enhancement signals are used to transmit additional high spatial frequency information.

**HDTV** (high definition television) is a new television system that provides dramatically better quality in a fashion that is not compatible with previous television systems. It generally requires more bandwidth for transmission than NTSC (for example 8.2 MHz in the case of the NHK MUSE system described later, or in excess of 20 MHz for a baseband signal).

The terms IDTV, EDTV, and HDTV are not always used consistently, so it is usually appropriate to give additional details when describing any particular system. For example, the numerous proposals before the U.S. FCC could by these definitions be called EDTV systems (where they are NTSC receiver-compatible) or HDTV (where they are simulcast), but that distinction in terminology undoubtedly has the connotation of a greater distinction among the systems than is justified. In Japan, on the other hand, there has really only been one incompatible system proposed, the 1125-line HDTV standard proposed by NHK, and so the terminology can be more consistently applied.

### **Initial HDTV Research and Funding**

Research into HDTV in Japan (and the world) was initiated by the NHK Research Laboratories. NHK is Japan's public broadcasting organization, roughly analogous to PBS in the U.S. NHK is noncommercial, and is supported

by "receiving fees" paid by most of the television set owners in Japan. Its primary function is to distribute nationwide two channels, one entertainment and the other educational. There are a number of commercial broadcasters in Japan supported by advertising revenues, and they have a reputation for providing more interesting and lively programming material than NHK. Every two months each household in Japan is visited by an NHK solicitor, who requests a donation of approximately \$16.<sup>1</sup> An impressive percentage of the population makes the donation (greater than 95%), in spite of the fact that the commercial broadcasters generally have a better reputation for interesting programming.<sup>2</sup> While many Japanese may resent having to pay for NHK broadcasts, they are nevertheless very loyal in their continuing payments. This continuing stable source of funding has been used to support the NHK Research Laboratories (with the current funding level of about \$20 million per year).

During the course of the NHK research program, much of the technology such as that of HDTV displays and cameras has been developed by participating companies. This is significant because it emphasizes that the process by which HDTV research was performed ensured that manufacturers also gained the expertise and technology for later commercialization. In these interactions, NHK generally paid for the material costs and the companies paid for their own labor costs (the latter undoubtedly much larger). In this way, the NHK research expenditures were leveraged into a larger program, and useful technology was developed by the manufacturing companies. Significantly, this approach allows each company to develop components with the assurance that these components will fit into a larger system, thus reducing their risk of loss of their investment. This also illustrates the willingness of Japanese companies to invest their own resources in this uncertain technology at a very early date. Sometimes this cooperation may also have been driven by other considerations, such as the manufacturers' desire to cooperate with NHK, a major customer for their equipment.<sup>3</sup>

### Signal Processing Technologies

One important point to keep in mind is that all the systems described, including those developed for analog modulation and channels, use digital signal

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<sup>1</sup> NHK sets the figure at \$20. [Opposing views of Japanese reviewers are presented in footnotes]

<sup>2</sup> NHK states this is not the case. According to NHK, the audience pays a receiving fee, since they have a lot of confidence in NHK's programs.

<sup>3</sup> According to NHK there is a lot of equipment for which NHK originally developed the technology and which these manufacturers put to practical use.

processing (DSP) technology extensively. Generally they are implemented by an initial analog-to-digital conversion, digital processing, and digital-to-analog conversion. This includes IDTV, EDTV, and HDTV (including MUSE). Thus, regardless of the modulation and transmission format, all television receivers of the future will require VLSI realization of DSP algorithms, as well as substantial amounts of memory.

*Compression.* The baseband video signal that emerges from an HDTV camera has a much higher bandwidth (in excess of 20 MHz) than is practical to transmit over most available transmission media (particularly radio channels). Hence the need for signal processing to compress the bandwidth to a more practical level (Ref. 1.6). This compression takes advantage of the redundancies in the signal (for example, in a still scene there is no new information in each succeeding frame) and the properties of the human visual system (for example, its tolerance for lower bandwidth in the color information, as opposed to luminance, as well as in the moving areas of the picture.)

Many Japanese companies are embarked on research programs into digital compression of HDTV with both storage and transmission applications in mind. The straightforward digitization of the NHK-format HDTV requires a bit rate of about 1.2 Gb/s, and Sony has developed a commercially available digital VTR that stores video at this rate (Ref. 1.7). While this rate can be supported by optical fiber, economic tradeoffs suggest the use of compression to lower rates. The cost of the compression and expansion will be justified by lower transmission or recording costs, at least in current technologies.

Initial efforts in digital compression were performed by NTT in connection with its early INS demonstrations, and used a bit rate of 400 Mb/s (Ref. 1.8). More recently, NTT has developed codecs at a rate of about 100 Mb/s (Ref. 1.9). We saw several demonstrations of hardware-implemented realtime compression algorithms for HDTV at bit rates in the 100 to 140 Mb/s range. These were not programmable realizations, but rather custom designs using catalog chips (no ASICs). The quality of the resulting images was quite good, with no noticeable artifacts, and definitely superior to MUSE-encoded HDTV. NHK Research Laboratories and KDD are working on digital compression of HDTV; NHK and NTT are also cooperating in this area.

While there has been much video compression research in the U.S., we would judge that Japan is one to two years ahead in the actual hardware realization of compression systems for HDTV.

*Modulation.* In addition to compression, the video signal must be modulated into a form appropriate for the transmission medium (for example, moved in frequency to an appropriate area of the broadcast spectrum). The modulation

methods can be divided into analog and digital transmission (Ref. 1.10). In the former, a continuous-time and continuous-amplitude signal is transmitted; whereas in the latter, the video signal is composed into a stream of bits that are then transmitted using one of a number of data transmission methods (Ref. 1.11). The straightforward digitization of HDTV results in a very high bit rate, about 1.2 Gb/s, which would require considerably more bandwidth for transmission than is required in analog modulation. However, the digitized HDTV signal also offers considerably more opportunity for compression before transmission, with the result that the actual transmission bandwidth is roughly comparable to analog using currently available signal processing and modulation methods. Analog or digital modulation, or possibly even a combination of the two, can be used on any of the media to be described below. Generally speaking, however, the emphasis has been on analog modulation on all media except fiber optics because of the bandwidth efficiency that can be more readily obtained. For magnetic storage, again either analog or digital modulation can be used.

*Digitization.* For the long term, digitization of the HDTV signal for either transmission or storage offers significant advantages, and will likely become commonplace. As previously mentioned, there is a greater opportunity for compression, and the subjective quality of the de-compressed picture can be superior to analog compression. The most significant advantage is the absence of degradation in transmission or in multiple recordings and playbacks for a digitized signal. It should be noted that this same property can be perceived as a serious copyright problem by program producers, as demonstrated by the digital-audio tape controversy in the U.S.

*Reception and Display.* As shown in Figure 1.3, the basic electronic components required in the implementation of any advanced television receiver are the same, whether it be IDTV, EDTV, HDTV, or analog or digital transmission. The received signal is first turned into a sampled digital format. In the case of direct-broadcast satellite or terrestrial broadcast, this requires a tuner/demodulator, followed by sampling and analog-to-digital conversion. For digital transmission via fiber optics, these steps can be skipped. The remainder of the receiver functions are implemented using, in all cases, digital signal processing together with significant amounts of memory. The final signal for display is converted from digital to analog.

### **Transmission Media**

The major media expected for near-term HDTV transmission are expected to be direct-broadcast satellite in Japan and Europe and terrestrial broadcast in the United States. For the longer term, there is keen interest around the developed world in transmission by fiber-optic cable.

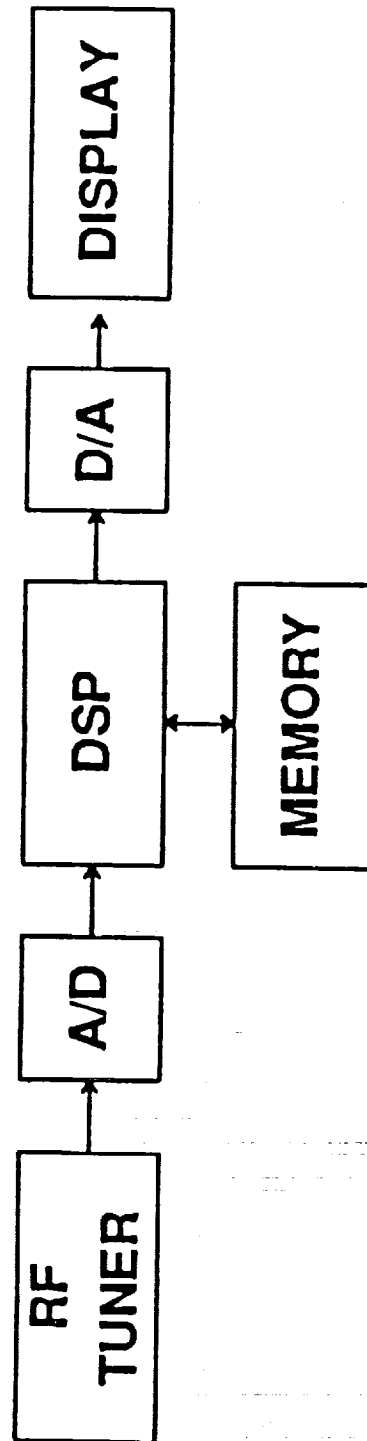


Figure 1.3. The basic steps in the implementation of an advanced TV system are the same for all the systems and for both analog and digital transmission.

*Direct-Broadcast Satellite.* Japan was the first country in the world to launch and initiate broadcast television service on a direct-broadcast satellite (DBS) in May 1984.<sup>4</sup> (Ref. 1.12) This was stimulated by the need to provide service to a number of small and remote islands that are difficult to reach by either United terrestrial broadcast or cable. Since NHK alone has the mandate to reach all the Japanese people, it has naturally been the leader in introducing DBS. DBS is also the medium that NHK has proposed for distribution of HDTV.

DBS makes an ideal medium for the rapid deployment of HDTV broadcasting in Japan because, compared to the U.S., it has a relatively small geographic area, and the local broadcasters are fewer in number and probably enjoy less political influence. DBS offers a more ideal channel than terrestrial broadcast, due to its greater bandwidth and lack of multipath distortion, and because it is immediately available to the entire country.

For the long term, three DBS channels of HDTV distribution are planned, two for the NHK channels and one for commercial broadcasters. The fact that NHK will be allocated two of the three channels (perfectly justifiable by its mission to reach remote islands with its two national channels) and the commercial broadcasters will be allocated only one makes this an attractive strategic move for NHK. To the extent that HDTV is successful, it should aid NHK more than the commercial broadcasters. The commercial broadcasters can be expected to respond by aggressively promoting EDTV broadcasting, and possibly by stimulating the more rapid deployment of optical fiber. On the other hand the commercial acceptance of HDTV may be somewhat hampered in the near term by the limited programming available, and by the fact that most of this programming is provided by NHK.<sup>5</sup>

NHK research oriented toward HDTV transmission on the available 27 MHz DBS channels culminated in 1982 in the announcement of the MUSE standard for DBS transmission (Refs. 1.13-1.15). MUSE was driven by the desire to transmit within a standard 27 MHz bandwidth satellite channel, using modulation techniques available and implementable in a 1980s timeframe. The latest version of MUSE, MUSE-E, generates an 8.2 MHz bandwidth baseband analog signal that is transmitted over the satellite using a standard 27 MHz transponder and frequency modulation (FM). The FM modulation provides immunity to the nonlinearities normally present on the microwave transmitter, and enables the transmitter to be driven at higher power levels. It also provides some

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<sup>4</sup> The U.S. ATS-5 satellite did some broadcasting to India in the mid 1970s.

<sup>5</sup> According to NHK, a lot of HDTV programs are being produced out of NHK by commercial broadcasters. (See IWP 11/9-23, 26)

signal-to-noise advantage due to the bandwidth expansion in the FM modulation process (8.2 to 27 MHz).

The DBS transmission of HDTV in Japan will use the MUSE analog modulation technique. The receiver consists of a 0.5 meter dish antenna, RF demodulator, MUSE decoder, and display. The current DBS satellite is called BS-2, and HDTV transmission by MUSE using BS-2 was initiated on an experimental basis by NHK in June 1989 for one hour per day. Approximately sixty<sup>6</sup> receivers have been positioned around the country in public places (department stores, train stations, etc.) to receive these broadcasts. The purposes of these broadcasts seem to be to generate public support for HDTV, interest consumers in purchasing sets at a later date, and gain experience in HDTV production and broadcast.

NHK indicated to the JTEC panel that it plans HDTV broadcasts of about six to seven hours per day by 1991, using the next generation BS-3 satellite. As previously mentioned, three HDTV MUSE broadcast channels are planned, two for the two NHK channels (one entertainment, one educational), and the third for the use of commercial broadcasters.<sup>7</sup>

*Terrestrial Broadcast.* Terrestrial microwave broadcast is the primary medium for delivery of television in the major cities of Japan, and the primary medium available to the commercial broadcasters. There is no plan to transmit HDTV by terrestrial broadcast. In fact, the receiver manufacturers expressed skepticism to us that resolution and quality comparable to MUSE is possible with terrestrial broadcast, given the multipath impairments and the limited bandwidth available. The consensus in Japan is that systems of the type being considered in the U.S. by the FCC cannot achieve a quality comparable to the NHK HDTV system.

On the other hand, the JTEC panel encountered significant skepticism among receiver manufacturers as to the viability of the NHK MUSE system for commercial broadcast in Japan. There are many who feel that EDTV is a more viable option for the near term. First, EDTV may offer a significant enhancement of quality (although certainly not comparable to HDTV) for a much lower cost than HDTV. Second, HDTV offers a significant improvement in quality only for the larger screen sizes, whereas it is questionable how large a screen can be accommodated in the typical small Japanese home. In the

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<sup>6</sup> NHK puts this figure at ninety.

<sup>7</sup> According to NHK, Mpt has a plan to use one of its spare transponders on BS-3b, which will be launched in 1991 exclusively for HDTV in order to increase the length of HDTV broadcasting. However, NTSC signals will be broadcast using two channels for NHK and one channel for the commercial broadcaster (JSB) in BS-3b.

commonly feasible screen sizes, EDTV may offer substantially the same quality as HDTV. Third, EDTV offers a much larger program choice, the bandwidth is smaller and it can be accommodated on terrestrial broadcast, and the broadcast is more attractive to programmers and advertisers since there is already an embedded NTSC audience.

Therefore, there appears to be a struggle developing in Japan between NHK and the commercial broadcasters corresponding to the competition between HDTV and EDTV. The widespread introduction of EDTV-2 in Japan, if it occurs, may be a significant impediment to the commercialization of MUSE, and HDTV in general.<sup>8</sup>

A first version of EDTV, EDTV-1, was scheduled for broadcast in late 1989. This version is actually closer to IDTV, since the primary modifications are to the receiver. The transmitter modifications are limited to the insertion of a training signal for ghost cancellation in the receiver (to enable the effects of multipath impairments to be removed), and some filtering to reduce the crosstalk between luminance and chroma inherent in the NTSC format (using techniques similar to those proposed by Farouja Laboratories in the U.S.). It is fair to say that the improvement observed by the average viewer of EDTV-1 will be minimal, particularly as compared to currently available IDTV receivers.

One of the significant advances of HDTV is the wider aspect ratio, not only subjectively preferred but also consistent with the aspect ratio of movies. A significant shortcoming of EDTV-1 is that it uses the same aspect ratio as NTSC.

The second version of EDTV, EDTV-2, is scheduled to be standardized within the next two<sup>9</sup> years. However, there has been no progress toward a standard, and there is suspicion that NHK is delaying progress, since it views EDTV as narrowing the gap with HDTV, thereby reducing the chances for success of the latter.<sup>10</sup> The process of choosing a standard for EDTV-2 in Japan is not even as

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<sup>8</sup> According to NHK, many manufacturers do not think that EDTV is a more practical choice than HDTV in the near future after having reviewed the very small penetration of EDTV receivers in these two years. NHK states that it is not the case that NHK is competing with commercial broadcasters in the sense that the former is developing HDTV and the latter are developing EDTV. NHK states that it understands the importance of development of EDTV and plays important roles in this development.

<sup>9</sup> NHK puts it at three years.

<sup>10</sup> According to NHK, development of EDTV-2 is being conducted in BTA with the participation of NHK, commercial broadcasters, and manufacturers. NHK is actively cooperating with BTA to develop EDTV-2, proposing some important technical ideas. NHK states that it understands the importance of the improvement of the picture quality in terrestrial broadcast.

far along as the similar process in the U.S., based on the current FCC proceedings. In fact, the Japanese strategy may be to wait for the U.S. standard, and then choose a compatible standard, thereby aiding the receiver manufacturers.

In summary, there appears to be direct competition in Japan between HDTV (primarily advocated by NHK) and EDTV (primarily promoted by the commercial broadcasters). In spite of the consensus position presented to the outside world by Japan that HDTV is the television system of the future, there is considerable disagreement about this within Japan. The "consensus" position is in the best interest of NHK, and is evidently driven by its political power. Many organizations outside of NHK, such as the commercial broadcasters, appear to favor the EDTV approach for Japan. (Note that the JTEC panel did not visit any commercial broadcasters to obtain direct verification of this statement.) Most of the receiver manufacturers are pursuing both approaches, but many appear to be more optimistic about the success of EDTV in Japan.

Despite some skepticism about the near-term potential of HDTV as a broadcast television technology, many Japanese manufacturers do favorably view the market for HDTV in its industrial applications, as discussed later. This, in addition to the political power of NHK, goes a long way toward explaining their willingness to invest in developing this technology.<sup>11</sup>

Also, it should be emphasized that like HDTV, EDTV receivers require substantially more signal processing electronics and memory than today's NTSC receivers. To the extent that they are commercially successful, both HDTV and EDTV equipment will have a considerable impact on the commercial markets for electronics components and on the technological capabilities of their manufacturers.

**Cable (CATV).** In contrast to the U.S., CATV is not a significant factor in Japan. There are about 3.6 million subscribers on Japanese cable systems, representing a fairly insignificant portion of the population (Ref. 1.12). Nor is CATV likely to become a significant factor, since any analogous distribution system installed in the future would likely use optical fiber. Thus, in contrast to the U.S., CATV is not viable in Japan as a medium for establishing HDTV broadcasting.

**Optical Fiber.** By far the highest quality HDTV service could be provided via fiber optics, since it could be used for digital transmission at bandwidths much

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<sup>11</sup> NHK states that NHK and commercial broadcasters are working together in developing EDTV. Among commercial broadcasters there are different views on HDTV and EDTV because some of them prefer HDTV while others prefer EDTV.

higher than either satellite or terrestrial transmission. At bit rates of 100 to 140Mb/s per HDTV channel, a single fiber to the home could easily support four to eight HDTV channels simultaneously. If the fiber network were constructed on a switched basis rather than a distribution basis (the latter analogous to the present CATV networks), then an essentially unlimited number of channels of HDTV (as well as lower resolution TV) could be provided. The quality that can be obtained currently at these bit rates is substantially better than MUSE or EDTV, and there is considerable opportunity for further reductions in bit rate. Furthermore, the use of digital transmission all the way to the home would ensure that there would be essentially no transmission impairments.

In Japan, optical fiber networks for delivery of HDTV and other telecommunications services would be installed by the Nippon Telephone and Telegraph Co. (NTT). This is envisioned as a part of a general concept called the Information Network System (INS) (Ref. 1.16). The INS is an experimental system that is testing the delivery of many telecommunications services through digital transmission directly to customer premises.

Like NHK, NTT is overseen by the Ministry of Posts and Telecommunications (MPT). Thus, it is likely that MPT would perform coordination of the activities of NHK and NTT. To some extent, the interests of NTT and NHK would run counter to one another. To the extent that NTT installs optical fiber networks, this would likely provide more extensive HDTV transport services to the commercial broadcasters, and not necessarily serve the best interests of NHK.

Both NTT and NHK told the JTEC panel that there is no immediate plan for installation of fiber to the home, primarily on the basis of the high installation cost. Clearly this is currently a much more expensive option for HDTV distribution in Japan than DBS. On the other hand, a fiber network would offer the possibility of a number of other broadband telecommunications services, which could help to defray the higher costs.

While there was no indication of any plans for fiber networks to the home for the next five to ten years, fiber is currently being installed for "trunking" applications, i.e., delivery of television programming to terrestrial broadcast stations around the country. Fiber is also being installed to businesses for data and video conferencing applications. Since the near-term plans for HDTV are to use DBS, there should be a much smaller need for HDTV fiber trunking. In spite of any near-term plans for fiber distribution of HDTV, there is considerable investment by NTT, and also by NHK, in digital compression technology for HDTV. There is also similar activity in several manufacturing companies. Applications of this technology could include optical fiber (both trunking and distribution to the home) and digital recording. While there has

been activity in the U.S. in digital compression of HDTV, this author is aware of no working realtime compression systems at a rate of 100 Mb/s. The JTEC panel saw at least one such system in Japan, and would therefore have to conclude that Japan is one to two years ahead of the U.S. in developing digital compression of HDTV signals.

*Recording Media.* The storage or recording of HDTV is obviously important for production of programs, including near-term use in the production of movies (replacing film). It is also important in distributing HDTV program material in the absence of transmission media, for example, in the U.S. prior to the establishment of transmission standards and facilities. Recording is also important in the HDTV equivalent of the camcorder.

There are a number of advanced video recording developments underway in Japan, most using the baseband analog and digital approaches. Manufacturers have been active in the design of HDTV magnetic recorders for both studio use (the video tape recorder, or VTR) and for home use (the video cassette recorder, or VCR). Most of the manufacturers we visited had prototypes of both types of recorders, and in some cases they are commercially available. Most of the manufacturers were working on both analog and digital recorders. In most cases, the analog recorders were for the wider bandwidth baseband signal, rather than for recording in the narrower bandwidth MUSE format. This is necessary for VTRs, given the degradation in quality in MUSE, although MUSE VCRs would be a viable commercial product. However, a MUSE VCR has the significant disadvantage that a MUSE encoder is very expensive, and thus a MUSE camcorder would probably not be cost-effective.

### **Receiver Types**

*IDTV.* Virtually all the television manufacturers have ongoing programs in development of IDTV sets. Clearly the "high-end" television market is the most profitable, and therefore this activity is commercially important. IDTV television sets are now available commercially from both Japanese and European manufacturers.

*EDTV.* Most of the manufacturers we visited were developing EDTV-1 sets. This is a natural extension of IDTV developments. The extent of EDTV developments beyond this is less clear. The most aggressive research and development program in this area is at Hitachi Central Research Laboratory, led by a pioneer in EDTV, Dr. Fukinuki (Ref. 1.17). His laboratory has developed an EDTV system with standard 4:3 aspect ratio, and is currently refining EDTV systems with 16:9 aspect ratios that use both the letterbox and side-panel approaches.

The quality of the EDTV pictures the JTEC panel saw demonstrated is impressive, and would seem to offer stiff competition to HDTV, especially given the wider availability and the lower cost.<sup>12</sup> However, one important caveat is that all the systems we viewed, both HDTV and EDTV, were in a studio environment and were not subject to transmission impairments. DBS-transmitted HDTV is likely to achieve a quality close to that we viewed, but it is not clear how the EDTV systems will stand up with actual terrestrial or CATV channel impairments.

*Compatible MUSE Systems.* Interestingly, NHK is also developing advanced television systems (ADTV), which is a similar concept to EDTV. This work is in response to the U.S. FCC proceedings which seek to define a terrestrial broadcast system. NHK has modified its MUSE-E format, already in use in Japan, to generate Narrow-MUSE, MUSE-6, and MUSE-9 (Ref. 1.18). Its motivation for this development is not clear, but most likely the objective is to preserve MUSE in some form, given that MUSE-E has been rejected for the U.S.

Narrow-MUSE is a 6 MHz bandwidth version of MUSE (as compared to 8.2 MHz for MUSE-E), and will fit within one standard broadcast television channel. MUSE-6 and MUSE-9 are receiver-compatible to NTSC, where the latter requires a 3 MHz enhancement channel. They are thus essentially EDTV systems in accordance with our earlier definitions. These systems were demonstrated at the National Association of Broadcasters Convention in May 1989 in an attempt to generate support in the U.S. These systems were developed quickly by modifying MUSE encoders and decoders. Considering their short development time and the less-than-optimum approach of modifying a different system, it is not surprising that the picture quality of these systems suffer somewhat in comparison to some other EDTV systems that have received a longer development. In particular, the NTSC-receiver picture for MUSE-6 and MUSE-9 was noticeably degraded.<sup>13</sup>

*HDTV.* All the HDTV developments that we saw, including cameras, VTRs, VCRs, and receiver/displays, were based on the NHK 1125 interlaced production format. We saw a number of demonstrations of working HDTV systems, including both baseband and MUSE.

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<sup>12</sup> According to NHK, the cost of a wide screen and wide aspect ratio EDTV receiver may be approximately the same as that of an HDTV receiver, because of complicated signal processing which is necessary to widen the aspect ratio and increase luminance and chrominance resolution with keeping with compatibility with NTSC.

<sup>13</sup> NHK states that the picture quality of MUSE-6 or MUSE-9 are approximately the same as that of any other ATV system. According to NHK, it is difficult for any system to have high picture quality in 6 MHz bandwidth while keeping compatibility with NTSC.

The quality of MUSE-decoded HDTV is somewhat dependent on the design of the decoder. All the systems we saw had noticeable artifacts in dynamic portions of the picture. Undoubtably this is fundamentally dependent on the MUSE format.

It is not clear how the general viewer would react to these artifacts, but they are readily discernible to the expert.

A VLSI implementation of the MUSE decoder is currently being developed by six companies in cooperation with NHK. This development includes 26 different ASIC chip designs. A complete decoder includes about 100 chips, including 50 catalog chips and 50 ASIC chips. The precise status of this development is unclear. All chips have been silicon. We heard from some sources that some of the chips were not yet functional, and from others that the board was working.<sup>14</sup> The development was announced in an NHK press release in early June 1989.

Due to the large investment in an uncertain market and some skepticism about MUSE, some manufacturers were initially reluctant to join this development effort, but were pressured by NHK to participate.<sup>15</sup> We inquired as to the opportunities for licensing MUSE technology from NHK, and were told that the technology would be freely licensed to all companies, domestic and foreign, with each paying the same license fee. Since our visit, a technology licensing agreement was in fact announced with TI Japan.

We also inquired at several manufacturers as to the difficulty they would have in developing and manufacturing equipment for a non-MUSE standard, such as an incompatible standard that might be adopted in the U.S. The consensus was that all standards are likely to have the same basic technology, and development to a new standard could occur quickly. The time from standardization to commercially available equipment would be about two years. This is quite a bit faster than most U.S. companies could respond, especially those that wait for the establishment of a standard before they begin their development efforts.

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<sup>14</sup> NHK reports that MUSE decoders with LSIs have already been demonstrated at the open house of the NHK Science and Technical Research Laboratories in 1989. Several manufacturers have already announced their intentions to sell MUSE decoders on the market.

<sup>15</sup> According to NHK, NHK has never intended to put any pressure upon manufacturers. NHK and manufacturers agreed to do the development together.

## **INDUSTRIAL APPLICATIONS OF HDTV TECHNOLOGY**

While many manufacturers are skeptical about HDTV broadcasting, they have invested heavily in HDTV development for several reasons, including pressure from NHK, particularly when it comes to developing hardware for MUSE.<sup>16</sup> HDTV is a natural evolution of the video technology and is driving a number of technologies with commercial potential, including displays, magnetic recording, and signal processing. Manufacturers are also investing in HDTV because of its potential for industrial applications, such as training, printing, and graphics.

Japanese manufacturers, particularly Sony, see that such near-term commercial applications in industry can offset their development costs. Japanese companies generally separate research from development costs, and do not expect that research costs be recovered from equipment sales in any specific time period. However, development costs must generally be offset by expected equipment sales within a reasonable period.

A few of the perceived applications of HDTV in industry (in which we include training and education) include the following:

- Movie production, replacing film
- Projection of movies in theaters, eliminating the local film projector
- Industrial and educational training video
- Medical imaging
- Printing and graphics
- Production of NTSC and similar resolution television programming

As a specific example, we saw at Sony a medical training video of an operation in progress. The video resolution and color rendition were perceived as adequate for training of medical students; thus, such videos may be used to reduce the time students must spend in actual operating rooms.

## **IMPLICATIONS FOR THE U.S.**

Given the strong presence of the Japanese in the consumer electronics markets and their near dominance of television and video products, HDTV is a natural

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<sup>16</sup> NHK states that they did not exert any pressure. The manufacturers are doing their business, estimating the progress of HDTV broadcast. None of them wants to be left behind the others.

progression in the development of their industry. Not only does it offer possibilities for future consumer products (the exact time frame is unclear), but there likely will be sufficient industrial applications to justify much of the development cost. In addition, there is significant technology spinoff into other marketplaces.

### **The Institutional Context for the Development of HDTV in Japan**

*Initial Development.* The origins of HDTV in Japan are interesting in that the early developments seem not to have been motivated by visions of dominating world markets in consumer electronics. Rather, HDTV arose out of a desire to advance television systems generally, and to advance the fortunes of the broadcasting agency that supported the research, NHK, in its competition for viewers. The parallels to the development of color television in the U.S. are striking--a cooperation through common ownership between a broadcaster (in that case NBC) and an equipment manufacturer (in that case RCA). In Japan, HDTV has been driven by a broadcaster, NHK, with the cooperation (or at least acquiescence) of the equipment manufacturers.

Perhaps the most striking lesson that we can learn from the development of HDTV in Japan relates to the long-term focus of the research performed by NHK Research Laboratories, a quasi-public research laboratory.

*R&D Funding.* HDTV research was supported not through equipment sales, but through revenues derived from service provision by NHK, almost in the form of taxation.<sup>17</sup> This system of finance is illustrated in Figure 1.4. Both NHK (in broadcast television) and NTT (in telephony) receive service revenues, which they in turn use to support long-term research in underlying technologies important to those industries. In each case, they involve equipment manufacturers in that research by obtaining from them prototypes of equipment relevant to that research. These manufacturers in fact make substantial financial contributions to the research, since they are reimbursed only for material expenses and not for labor expenses.<sup>18</sup> What seems to be most critical about this symbiotic relationship is the overall direction of the research provided by the service provider (NHK or NTT). NHK and NTT define the overall system concept being researched, and "farm out" portions of the system to different manufacturers. The importance of this arrangement is that no individual manufacturer has to take the risk or make the investment to develop the entire

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<sup>17</sup> According to NHK, the receiving fee is not a form of taxation because there is no penalty stipulated in the broadcast law if the receiving fee is not paid.

<sup>18</sup> NHK states that the manufacturers cooperate with NHK and NTT because NHK and NTT have their own abilities for the development of new technologies.

system. Rather, each manufacturer can develop only a portion of the system knowing that its piece will fit into an overall system concept.

The parallels to the financing (and successes) of Bell Laboratories in the years prior to divestiture are striking. In that case, AT&T embodied both the service provider and manufacturer functions, but service revenues were used to finance much of the long-term research and development. This type of revenue is a much more stable source of financing.

Another lesson for the United States is the participation of Japanese industry in the research, in effect obtaining a partial subsidy for its own long-term research, but also being willing to invest its own resources in a project with a very distant payoff.

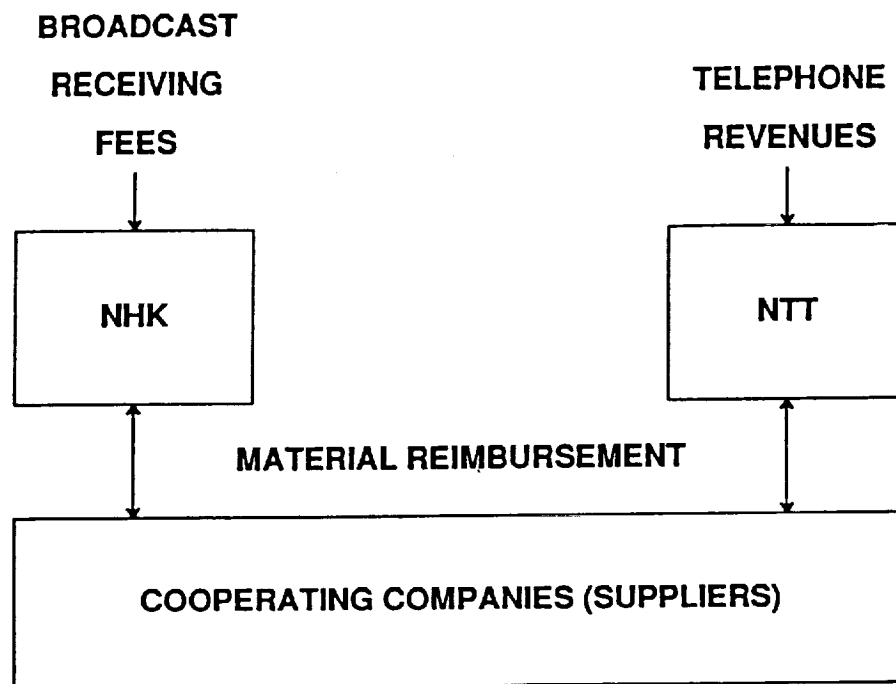


Figure 1.4. The Method of Finance of Long-Term Research Into Television and Telecommunications Systems in Japan

*The Need for a Common Standard.* Unfortunately for the Japanese, it would appear to be very difficult to establish HDTV as a commercial opportunity solely within Japan. For one thing, many of the producers of programming material are outside Japan, and would be unlikely to produce material in a

special format solely for that market. For another, HDTV offers an advantage over competing advanced television systems only when viewed on a big screen, and the small floorspace of Japanese homes makes big screens more problematic than in the U.S. Thus, to really cash in on their investment, the Japanese companies need the U.S. market, and this may explain their increasingly accommodating position with respect to establishing a joint standard.

*Future Directions.* Having reviewed the current status of R&D related to modulation and transmission of high-resolution video in Japan, we can now speculate briefly on likely future directions of Japanese technology in these areas.

With respect to television broadcasting and receivers, it seems clear that the major Japanese television manufacturers will continue to develop all three levels of television technology: IDTV, EDTV, and HDTV. HDTV will be driven by the needs of NHK, while EDTV will be driven by the needs of the commercial broadcasters. The standardization of EDTV seems to be currently on hold, probably pending the choice of a terrestrial broadcast system by the U.S. FCC. When the FCC chooses a terrestrial broadcast system, Japan will likely be the first to offer receivers commercially that conform to this standard, and will likely adopt the same standard for its terrestrial broadcast.

The future development of the incompatible HDTV system will also depend to a great extent on what happens in the U.S. It will be difficult for Japan to establish a profitable HDTV receiver manufacturing business on the basis of the Japanese market alone, because of the lack of availability of programming, the more limited economies of scale, and the limited space in Japanese households for the large HDTV screens. Thus, Japan will attempt to establish a parallel market for its HDTV system in the U.S. on media other than terrestrial broadcast--VCR, cable, direct-broadcast satellite, or fiber optics. If necessary, it will adapt the system to conform to the needs or constraints of the U.S. market.<sup>19</sup>

Meanwhile, Japan, and especially Sony, will proceed at full speed on industrial and production applications of HDTV. HDTV technologies, such as signal processing and displays, will also be adapted to information system products.

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<sup>19</sup> According to NHK, it is now clear that the terrestrial ATV system in the U.S. will be different from the EDTV-2 and the MUSE because the U.S. FCC has decided to adopt a simulcast ATV system which is channel-compatible with the present 6 MHz RF bandwidth. Japanese HDTV and EDTV systems will have their own domestic market for the above reasons.

### **Spinoff Benefits of HDTV Development**

The video developments in Japan have many secondary benefits in terms of the advancement of other technologies and capabilities. This is perhaps the greatest significance of HDTV--as a technology driver. The benefits of this accrue from the exploratory developments that have taken place, regardless of the independent commercial success of HDTV.

*Signal Processing Technologies.* Digital signal processing is important in its own right, including in military applications. But as an application of high-speed computation with realtime constraints, it is perhaps the most demanding application of high-performance computing. The computation rates of many special-purpose DSP processors far exceed those of the fastest general-purpose supercomputers. As such, DSP is an important training and testing ground for high-performance computing. The DSP component of HDTV compression and decompression is demanding, and the experience gained there can be applied in other areas, advancing computing expertise generally.

It should be noted again that whether the transmission and modulation is analog or digital is largely irrelevant; in either case, the largest electronics content of an HDTV or EDTV receiver is in digital (not analog) signal processing.

Due to Japan's emphasis on video applications, Japanese technology in DSP processors, and especially those oriented toward video applications, is quite advanced. The need for the development of video and HDTV compression algorithms and the testing of those algorithms has led to the construction of many multiprocessor DSP machines in Japan, including at NHK, NTT, and the manufacturers. These machines are not really much different from multiprocessor supercomputers. Hence, we will not be surprised to see Japanese companies in the latter market as a side benefit of their emphasis on video technologies.

*Semiconductor Technologies.* The content of semiconductors in HDTV sets will be very high, further strengthening the captive Japanese semiconductor makers to the extent that HDTV is a commercial success. For the nearer term, the greatest significance of HDTV is as a driver of semiconductor technologies in the performance direction. Efforts at cost reduction of HDTV receivers will drive digital semiconductor processors and memories toward ever higher speeds.

*Other Applications.* Other applications and industries in which the U.S. is quite strong are susceptible to obsolescence from electronic video technologies of which HDTV is a natural progression. These include film for still and movie cameras, printing, and medical imaging. It is clear that video and imaging in its

many forms and manifestations will be one of the major industries of the coming decades, and if present trends continue, the U.S. may be destined to play a secondary role.

## CONCLUSIONS

From our visits it was evident, as expected, that Japan has a clear lead over the U.S. in most aspects of high-performance video signal processing research and development. Significantly, this lead includes the digital compression and processing of video.

If Japan has a weakness, it stems from the long history and vested interest in specific HDTV standards, modulation methods, and transmission media. If one started today to develop an HDTV system using the most modern technologies, the resulting system would differ in some important respects from that which has been developed in Japan. In particular, it would undoubtedly emphasize more digital compression and transmission, and optical fiber would probably play a much larger role. This presents an opportunity for the U.S. to bypass the slightly antiquated MUSE technology into a more advanced system. However, make no mistake about it, the Japanese manufacturers will have both the capability and the will to develop equipment for any standard and system developed in the U.S. Their current base of technology and experience should enable them to develop equipment compatible with almost any advanced television system in very short order.

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## CHAPTER 2

# EVOLUTION OF DISPLAYS IN JAPAN

Lawrence E. Tannas, Jr.

### INTRODUCTION

The concept of *Johoka Shokai*, the "Information Society," was presented in December 1980 in a report of the Japanese Information Industry Council (Ref. 2.1). *Johoka Shokai* is a broad concept in which integrated information and communication systems contribute to industrial productivity, resource and energy conservation, the solution of social and medical problems, an elevation of the human sense of self-worth, and even the promotion of world peace. When the JTEC HDTV panel visited Japan in June 1989, it appeared that the vision of an advanced information society is widely shared in the Japanese government and the electronics community. Since this concept was introduced, many Japanese government agencies, private industries, and consortia have implemented programs for the development of "New Media" which they expect to serve as the infrastructure of the emerging advanced information society.

HDTV is an integral part of this infrastructure. Many technical achievements for HDTV transcend their application to the television industry; by way of commonality in electronic implementation and high-resolution visual components, HDTV merges the functions of television broadcasting, cinematography, photography, printing, graphic design, telecommunications, and computer processing. There is a national emphasis in Japan to achieve *Johoka Shokai*, and HDTV is often considered the nucleus of the "New Media" infrastructure for this future society.

High-quality, high-resolution displays are critical to the success of HDTV. Japanese researchers have already achieved technical breakthroughs which allow for the production, storage, compression, and transmission of a video signal with

significantly greater amounts of visual information than that of NTSC-broadcast television. Affordable, quality display products will realize HDTV's potential to dramatically enhance the consumer's viewing experience.

Despite an array of technical difficulties inherent in high definition display development, government agencies and private Japanese firms are investing heavily in this research, and are highly committed to developing marketable HDTV displays in the near term. HDTV displays using either direct-view (up to 40-inch) or projection CRTs (40-inch and up) are already in production. Liquid crystal projection displays are still under development as an alternative to CRTs. Various types of direct-view, flat-panel displays are further behind in development, but should be in production by 2000. Thus, the technology is now available, or soon will be, for Japanese firms to produce high-quality, high-resolution display products for both consumer and industrial markets.

## **R&D ENVIRONMENT FOR ADVANCED TELEVISION SYSTEMS**

The following paragraphs describe some of the organizational and technical considerations which are currently determining the environment in Japan for the development of advanced consumer and industrial television equipment.

*High-Level Commitment.* Virtually all of the major Japanese electronics companies are working to develop HDTV and other related products based on high-definition video technologies. This is due in part to leadership by the Japan Broadcasting Corporation (*Nippon Hoso Kyokai*, or NHK), which is in a unique position in the Japanese television industry to state common objectives, set standards, and muster industry-wide support. The electronics industry in Japan also enjoys considerable support and funding for HDTV research from the Japanese Ministries of International Technology and Industry (MITI) and of Posts and Telecommunications (MPT).

NHK has been developing HDTV for twenty years. The complete concepts of HDTV studio production and recording, data compression, direct satellite broadcast, terrestrial broadcast, and CRT projection displays have not only been developed, but tested and exhibited in public forums such as EXPO 85 in Tsukuba, in showings on public screens of HDTV broadcasts of the 1988 Olympics from Korea, and daily one-hour broadcasts since June 1989, as well as in numerous electronics shows in Japan and other countries. Based on the progress to date, the Japanese government and the electronics industry expect to make 1990 the "year of high definition television (Ref. 2.2)." Planned for this year are the launch of a new direct broadcast satellite for HDTV, and extension of the hours of HDTV broadcast.

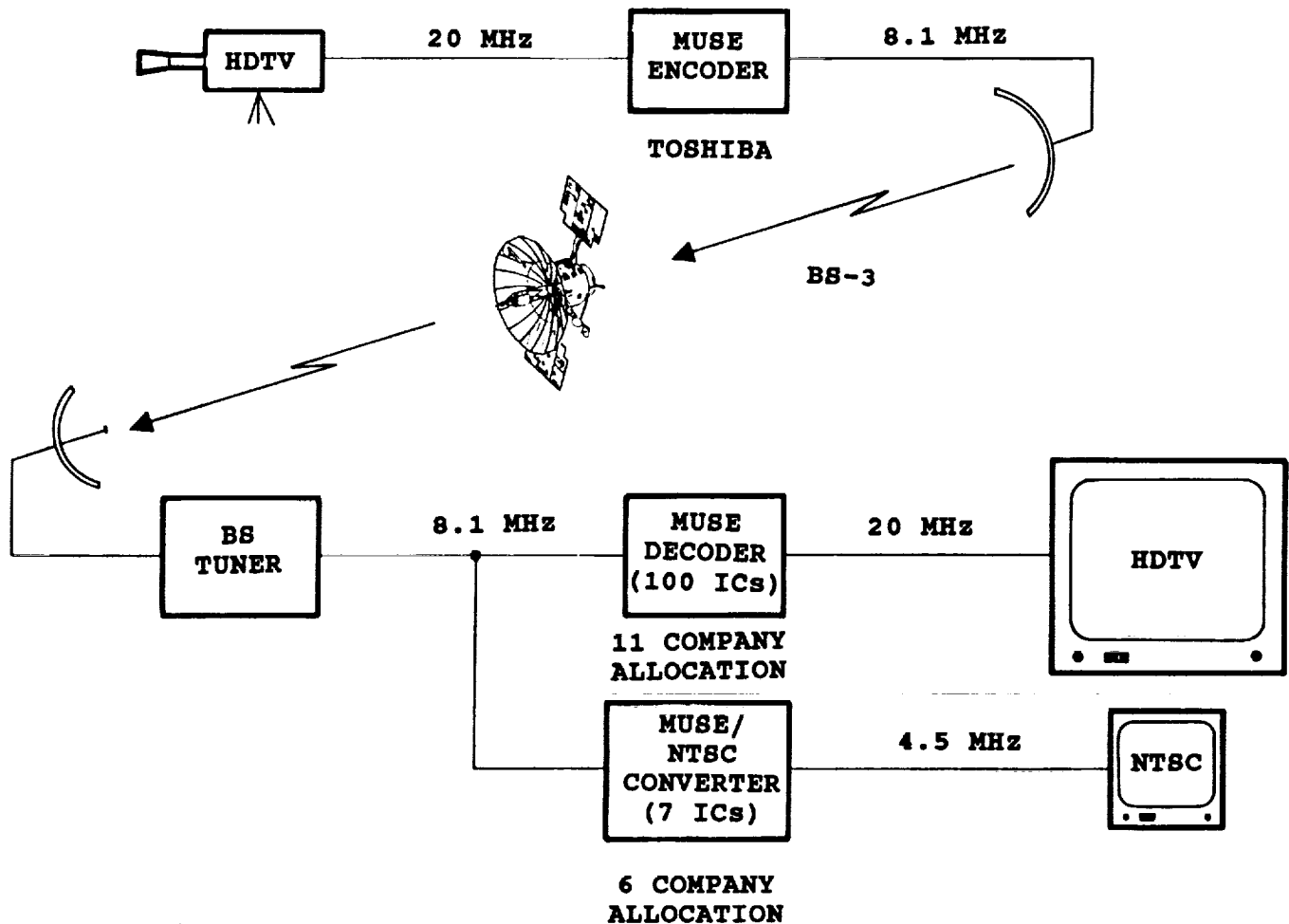
*Efforts to Establish a U.S. Standard.* Agreement on a production or source-material standard is essential to conversion of programming to appropriate distribution media, whether HDTV, existing television standards (NTSC, PAL, or SECAM), film, VTR, laser disc, etc., which can all be related through a common archival source. The Society of Motion Picture and Television Engineers (SMPTE) in the United States, with participation from Canada, Europe, and Japan, has spent considerable effort to achieve an internationally acceptable U.S. HDTV standard. SMPTE's recommendation for the 1125/60 standard to date has not been formally accepted in the U.S.

*Compatibility with NTSC Television.* In the United States, the FCC has ruled that any HDTV terrestrial broadcast television must fit in the existing 6 MHz NTSC bandwidth allocations and be compatible with or simulcast for viewing on existing NTSC televisions. There is also demand for compatibility from independent broadcasters in Japan. Japanese researchers have therefore devoted additional effort, with limited success, to making HDTV compatible with NTSC television, or at least compatible with the frequency bandwidth allocations for NTSC. Unfortunately, converting HDTV to NTSC raster causes considerable loss in resolution, and HDTV compression schemes (including MUSE) lose temporal and/or spatial information in the encoding and decoding processes.

*Improvement of NTSC Television.* Concepts to improve NTSC television have already been formally approved for use in Japan. These concepts are commonly referred to as IDTV (improved definition television) and more recently, EDTV-1 (extended definition television). With minor exceptions, the improvements in EDTV-1 are in the set. Improvements include progressive scanning, better use of the color signal, signal interpolation, and additional filtering. A newer system, EDTV-2, may include some expansion and transmission changes within the NTSC framework, as well as a 16:9 aspect ratio, while retaining reception compatible with EDTV-1 and standard NTSC television sets. EDTV-2 standard is scheduled for production in Japan two (or more) years hence.

*Simultaneous Use of HDTV and NTSC.* Dual television standards will continue indefinitely in Japan. HDTV will be distributed by direct broadcast satellite and viewable on special HDTV sets, with satellite antenna and tuner, and with MUSE decoder. HDTV programming will also be viewable on existing NTSC sets, at reduced resolution, utilizing satellite antenna and tuner, and electronic HDTV-to-NTSC converter box (see Figure 2.1).

NTSC television will continue by direct broadcast satellite and terrestrial broadcast as before, with upgrading of NTSC reception at the discretion of television viewers when they choose to buy a new IDTV or EDTV television set.



The complete HDTV distribution system, as viewed by NHK, depends upon the new domestic communication satellite. The MUSE data compression plays an important part by conserving bandwidth. The data compression is achieved by using 18 fields/sec. with eight sub-pictures for motion compensation. The use of the Ku band allows for home antennae of less than one meter in diameter and good penetration of atmospheric moisture. One satellite will cover the entire country of Japan, including its outlying islands.

Figure 2.1. NHK Distribution of HDTV

Source: Derived from NHK literature and modified.

*DBS Distribution of HDTV.* NHK has long planned the mass distribution of HDTV to be via direct broadcast satellite (DBS) (as shown in Figure 2.1), although by the year 2000 this would appear to be only one of several options, others being cable and fiber optics. Terrestrial broadcast of HDTV is less than satisfactory because of line-of-sight requirements, interference problems and ghosting, and the 6 MHz bandwidth allocation. MUSE, the HDTV compression technique developed by NHK, was a critical technical accomplishment. At its annual open house in June 1989, NHK announced the completion of a large-scale integrated electron MUSE decoder using twenty-six ASICs. The ASICs allow the decoder chip set to be reduced from 3000 ICs to 100 ICs.

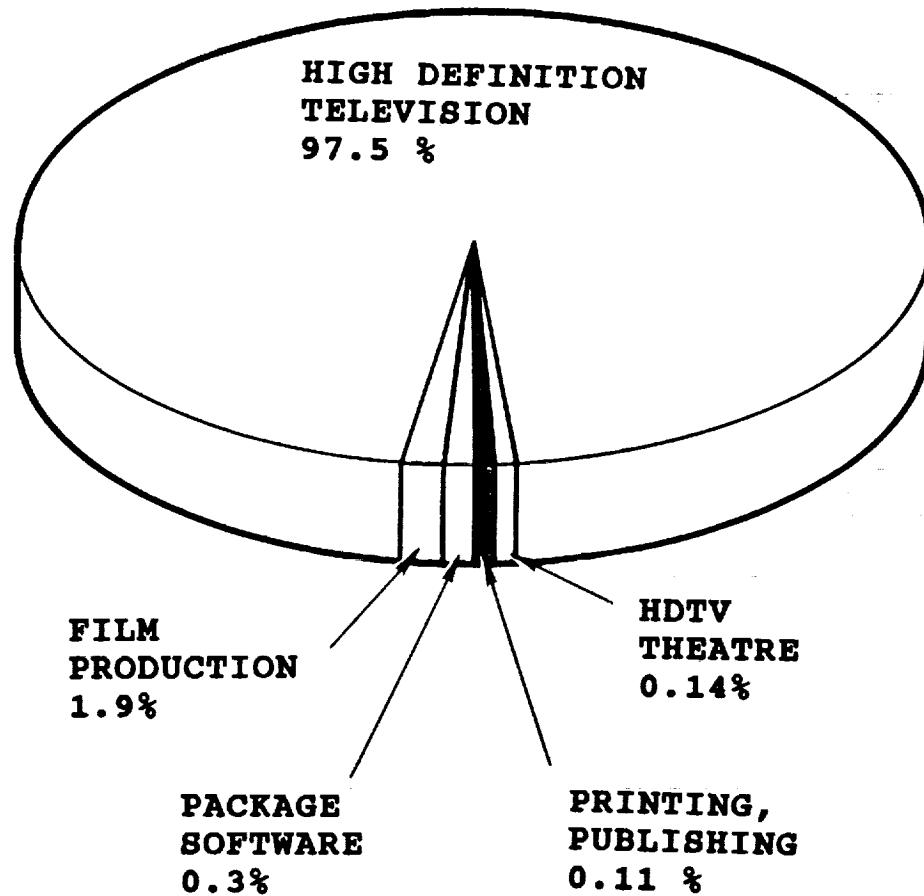
*Projections for Growth of HDTV Sales.* It is difficult to predict the growth of the Japanese HDTV industry; however, MPT has published projections of HDTV-related sales in Japan of 0.2 trillion yen in 1990, increasing to 3.4 trillion yen by the year 2000 (Ref. 2.3). MPT expects total sales for this period to be 14.5 trillion yen, almost all of which (97.5%) will be in consumer and industrial television sets (see Figure 2.2). These projections are useful as a measure of the level of expectation and commitment in the Japanese government and electronics community relative to the Japanese development of HDTV products.

## HIGH DEFINITION TELEVISION DISPLAYS

The display is a problematic component in high definition television systems. Not only must the HDTV display have a higher resolution and larger size than any previous consumer television product, it must also be affordable and be able to fit through the front door. In large-area HDTV displays, flat panel technologies would appear to be the answer to the problem of set volume, but these have not matured sufficiently to achieve either the resolution or the size required. There were no activities observed, or believed to exist, by the JTEC committee that would lead one to believe that flat panels could be in production much before the year 2000.

In lieu of flat panel displays for the near term, Japanese researchers have developed cathode ray tubes (CRTs) for HDTV sets in direct-view and in front- and rear-projection applications, through significant improvements in the technologies of the CRT. Several CRT products are now available which meet the high standards for HDTV viewing quality. Liquid crystal technologies appear to offer promising alternatives to CRTs, both in projection and in flat panel displays.

Table 2.1 shows various display types (Ref. 2.4), with their advantages and disadvantages at their present stages of development. Intensive display research continues in Japan, with a number of qualitative and quantitative goals for HDTV products.



The total 1990-2000 HDTV figure of 14.5 trillion yen is as estimated by the Ministry of Posts and Telecommunications committee for promoting HDTV. This is equivalent to one hundred billion U.S. dollars (at 145 yen to the U.S. dollar).

Figure 2.2. Projected HDTV-Related Sales, 1990-2000

Source: MPT, HDTV Promotion CTTEE handout to JTEC HDTV panel, as translated by Niko.

Table 2.1

## DISPLAY TECHNOLOGIES FOR HDTV

<u>TECHNOLOGY</u>	<u>ADVANTAGES</u>	<u>DISADVANTAGES</u>
DIRECT-VIEW CRT	HIGHEST OVERALL QUALITY <41"	DEPTH OF SET SIZE LIMIT <41"
PROJECTION CRT (FRONT AND REAR)	HIGHEST OVERALL QUALITY >40" ONLY COST EFFECTIVE METHOD FOR LARGE SIZE	DEPTH OF SET (REAR) REFLECTION OF AMBIENT ILLUMINATION (FRONT)
PROJECTION ACTIVE MATRIX LIQUID CRYSTAL DISPLAY	COST-EFFECTIVE FOR MEDIUM SIZE HIGH OVERALL QUALITY SINGLE PROJECTING LENS EFFICIENT LIGHT SOURCE	DEPTH OF SET (REAR) REFLECTION OF AMBIENT ILLUMINATION (FRONT)
DIRECT-VIEW ACTIVE MATRIX LIQUID CRYSTAL DISPLAY	FLAT PANEL HIGH QUALITY COLOR	SMALL SIZE (<14") HIGH COST
ELECTROLUMINESCENCE	FLAT PANEL	SMALL SIZE HIGH COST COLOR NOT DEVELOPED YET
GAS DISCHARGE (PLASMA PANEL)	FLAT PANEL	HIGH COST (LOW) LUMINOUS EFFICIENCY & BRIGHTNESS
LED	FLAT PANEL	SEVERE COST PROBLEM BLUE COLOR NOT YET DEVELOPED
OIL FILM PROJECTION (G.E. LIGHT VALVE AND EIDOPHOR)	VERY LARGE SIZE (>80") HIGH QUALITY	HIGH COST LOW LUMINOUS EFFICIENCY

## ERGONOMIC GOALS FOR HDTV DISPLAYS

The primary objective in the HDTV concept is to enhance the visual experience. The Japanese firms engaged in HDTV development intend to achieve this objective in three ways (Ref. 2.5):

1. Increase image size to make the subjects more life-like in size, thus improving realism of presence
2. Increase the peripheral image to enhance the illusion of actually being in the scene
3. Increase the resolution to satisfy human visual acuity in the same room lighting as is used with NTSC

In order to realize these goals, the HDTV set must be able to display substantially more visual information, and it must be both larger and proportionately wider than NTSC sets in use today. The wider-aspect image of HDTV (16:9, or 1.78:1) was chosen to approximate the publicly successful 1.85:1 aspect ratio which is the motion picture industry standard (Ref. 2.6). The aspect ratio of NTSC is 4:3 (or 1.33:1).

HDTV has approximately five times the picture elements, or pixels, of NTSC-broadcast television (see Table 2.2) (Ref. 2.7). Since the resolving power of the viewer is the same regardless of the type or size of image, the HDTV display can be optimally enlarged to 2.6 times (in diagonal) that of an NTSC television (see Figure 2.3). HDTV thereby retains about the same visual angle between pixels--one minute of arc between pixels for standard viewing distance--but with a much larger image size and wider field of view. Thus, if one is comfortable with a 19-inch NTSC set at a given viewing distance, a comparable HDTV set viewed from the same distance will be 50 inches in diagonal.

## CRT TECHNOLOGIES FOR HDTV

It is CRT high definition television products which are currently ready, and being marketed, for consumer and industrial use. To achieve the HDTV viewing objectives with CRT technology, Japanese researchers have realized improvements in the projection lens, phosphors, electron guns, and screen technology of the CRT. Sizes for CRT displays can be grouped into three ranges: direct-view CRTs below 41 inches; rear-projection cabinets from 40 to

Table 2.2

## A COMPARISON BETWEEN HDTV AND NTSC TV

	<u>HDTV</u>	<u>NTSC TV</u>
TOTAL RASTER TIME	1125	525
ACTUAL RASTER LINES	1035	483
HORIZONTAL PIXELS		
DIGITAL BASEBAND	1920	720
ANALOG BASEBAND	1020	448
INTERLACE RATIO	2:1	2:1
FIELD FREQUENCY	60 Hz	60 Hz
LINE FREQUENCY	33.75 KHz	15.75 KHz
VIDEO SIGNAL BANDWIDTH	30 MHz	4.2 MHz
AUDIO SIGNAL MODULATION	PCM	FM

107 inches, and front- or rear-projecting modules for screens above 100 inches for large theaters (see Figure 2.4). (Note that liquid crystal projection systems are also being developed for displays above 40 inches. Sharp demonstrated a liquid crystal HDTV projector at the Japanese Electronics Show in Osaka in October 1989).

### **Direct-View CRTs**

The Japanese CRT industry has pushed the screen size of direct-view CRTs (essentially the same system as used in standard television sets today) to 41 inches in diagonal. This display type now offers the highest HDTV image quality in sets 41 inches or under. However, besides being smaller than the optimal size for HDTV, this approach has the distinct disadvantage that the apparatus is so heavy and bulky that it is not practical to manufacture, distribute, or install in a typical living room.

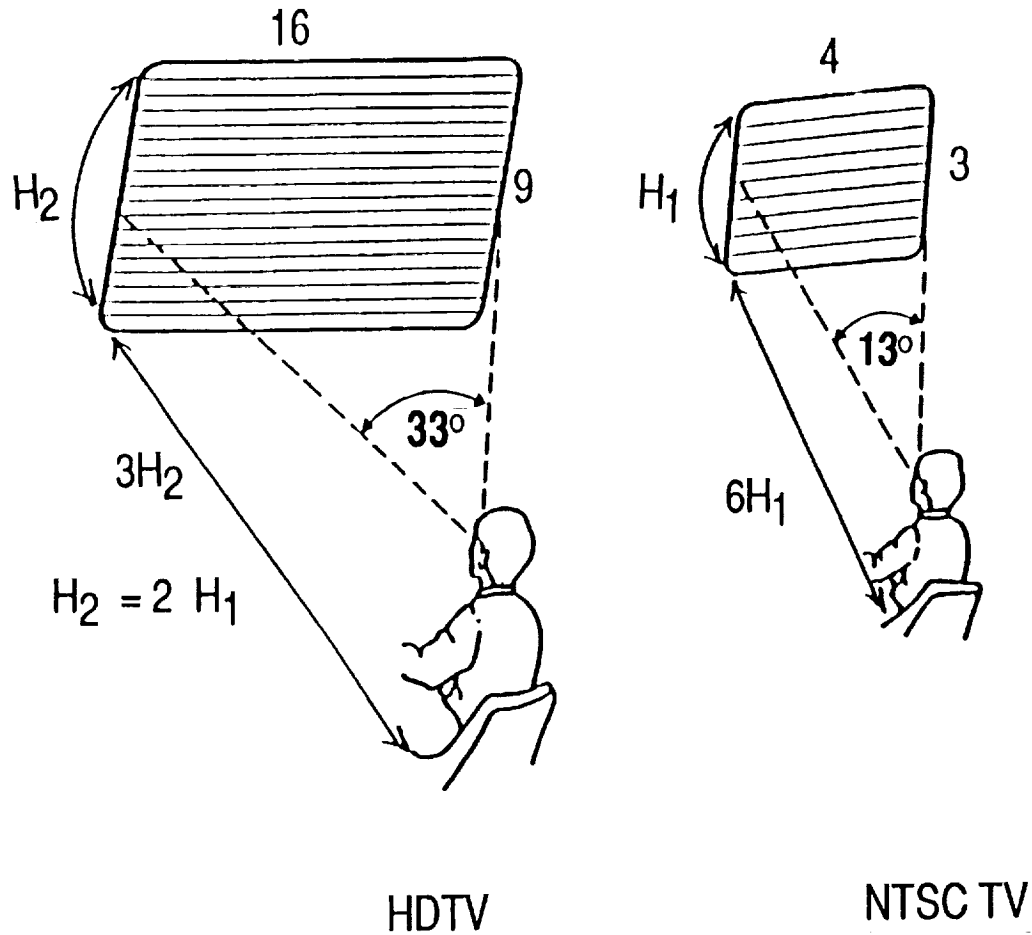
### **Projecting CRTs**

Projecting CRTs for large-screen cabinets and theater use offer promise for larger and brighter screens than direct-view CRTs, with narrower set depth and lower cost. The image quality and light efficiency of projecting CRT displays has improved dramatically in recent years. Although no major scientific breakthroughs have been incorporated into the latest projecting CRT displays, they do represent important engineering design advancements over previous approaches.

The evolution of projecting CRTs for large-screen televisions started (prior to HDTV application) with the single projecting shadow mask CRT and a high-gain custom-curved screen, followed by the Klass tube with built-in Schmidt optics, and finally, the three-tube approach for color without shadow mask and with refractive optics. These improvements were needed primarily to increase image brightness.

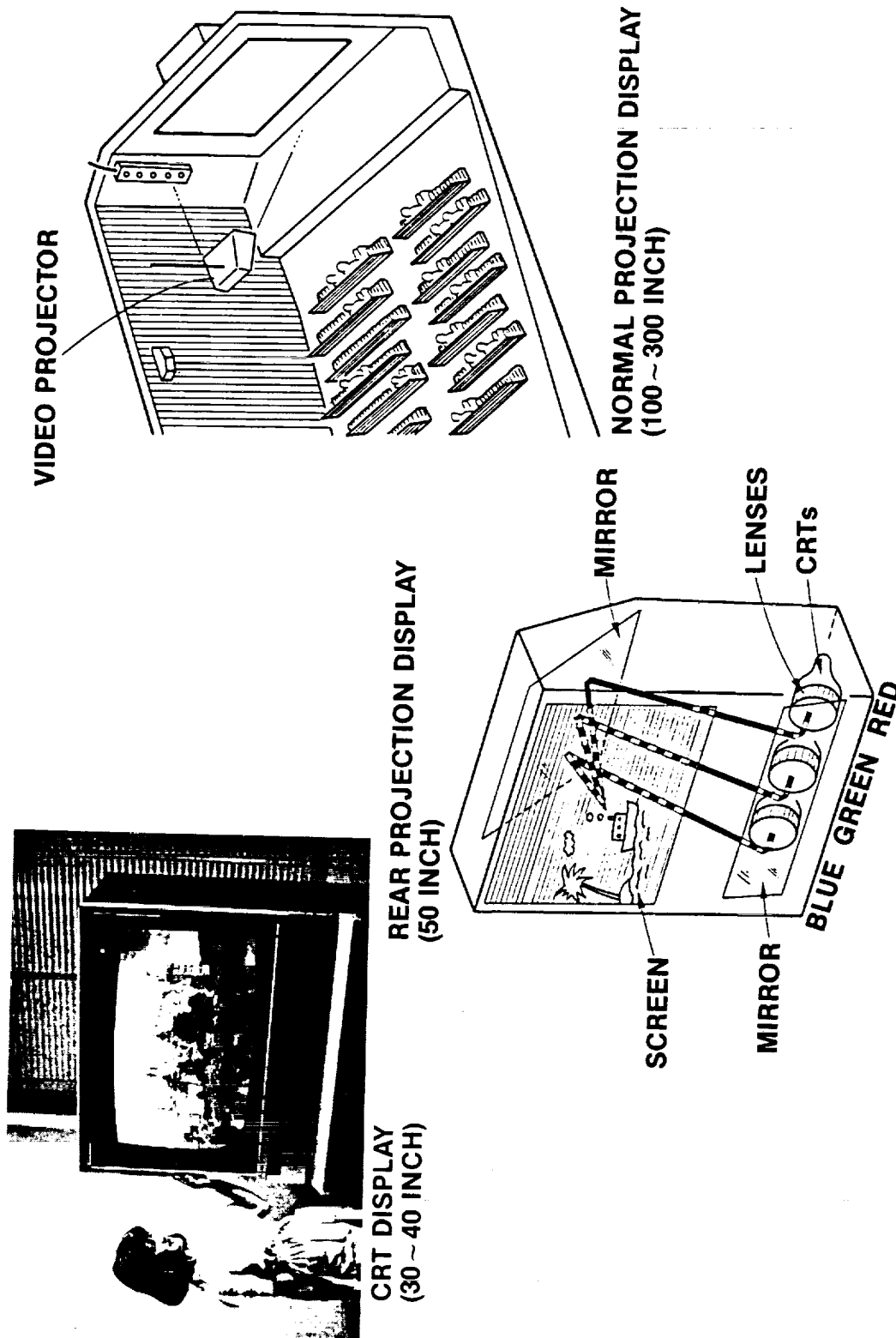
Increasing image brightness without necessitating the use of cooling fans has been one of the major research tasks for projecting CRTs. Innovations for improving light output include the following:

1. Using new mixes in phosphors for a 15% light output improvement (90% P-53 and 10% P-1)
2. Optically coupling the phosphor luminance into the faceplate with a thin film interference coating
3. Making a concave faceplate as part of the projection lens



The common metric in computing the ergonomic geometry is the vertical resolution of the human observer. It is assumed that the contrast ratio and brightness of the two systems is constant and at a level where the human observer can just resolve images at one minute of arc corresponding to the pitch of the raster lines. If the observer sits closer to the screen than suggested, he will see raster artifacts. If he sits farther from the screen than suggested, he will not see all of the detail provided in the image.

Figure 2.3. Ergonomic Comparison of HDTV and NTSC TV



The current HDTV displays use CRTs in three different configurations: direct-view for displays less than 40 inches in diameter, three-tube rear projection cabinet for displays approximately 50 inches in diameter, and a three-tube module for large theatres in both rear and front projection applications.

Figure 2.4. HDTV Display Configurations

4. Optically coupling the faceplate to the projection lens with a wetting fluid
5. Using the fluid between the faceplate and projection lens as a cooling means
6. Using a 10-element fast projection lens (F/1.0 to F/1.4) with fluid coupling to minimize internal reflections
7. Using a plastic aspherical lens to achieve a wide-exit projection angle and to reduce cost

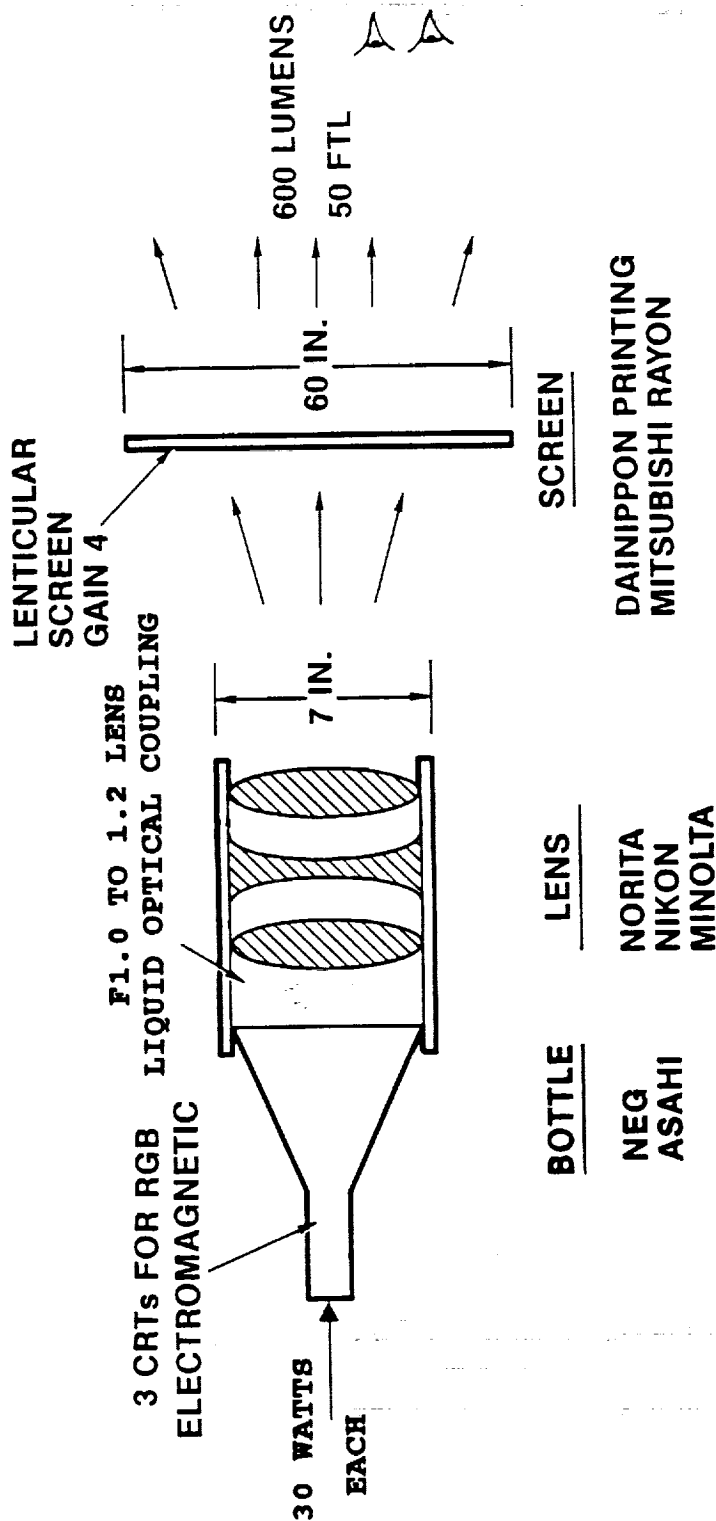
These sophisticated tube design concepts can be used in a rear-projecting cabinet, or in either front or rear projection for large screens over 50 inches. The 40-60-inch cabinet displays will use three tubes; projectors for larger screens will use three-tube modules in parallel, the number of modules depending on the size of the screen. A narrow deflection angle of 70° and electromagnetic focus are needed for the required high resolution.

Figure 2.5 shows the basic design of the CRT projection system. While this system does represent major improvements in HDTV display technology, there are still problems with the three-lens set, with less than optimal image brightness, with set depth (in rear cabinets), with throw distance requirements, and with reflected ambient illumination washing out the image in front projection systems.

### **The CRT Baseline HDTV Display**

The HDTV display type which is currently the most practicable and offers the highest performance in mid-sized HDTV cabinets is a 40-60-inch rear-projection console using three separate CRTs (for red, green, and blue), each approximately 7 inches in diagonal. It is similar to that available today for large-screen NTSC television.

One such model is the 40-inch Hitachi C42-Px1 (see Figure 2.6) (Ref. 2.8). As compared with a 40-inch direct-view CRT, the Hitachi C42-Px1 has a 25% savings in depth, a 50% savings in weight, a screen which is more than ten times as bright, and greater luminous efficiency (Ref. 2.8). This improved efficiency comes about by the optimization of the CRTs and a screen gain of five, at the cost of a slight loss in resolution and viewing angle. The screen plays a unique role by causing light which would be lost on the floor and ceiling to be directed at the viewing audience, and ambient room lighting to be absorbed rather than reflected back at the audience. This model sells for about \$3,000--a price comparable to that which U.S. consumers paid for color televisions in the 1950s.



The heart of the CRT display rests in the CRT projecting system. The new projecting tubes in Japan represent a very highly-engineered and optimized optical system. The tube faceplate utilizes optical-coupling thin films between the phosphor and glass with a concave faceplate, an optical element in the projecting lens, fluid-coupled for cooling and minimum scattering, a ten-element projecting lens, and utilization of a highly-optimized screen completing the optical path. A large infrastructure has evolved in the Japanese industry to provide the components needed in this new high-resolution tube.

Figure 2.5. CRT Projection System

## **ACTIVE-MATRIX LIQUID CRYSTAL PROJECTORS**

Because of the remaining problems in CRT projectors, a number of Japanese electronics firms are pursuing the development of liquid crystal projectors as an alternative to CRTs. Seiko-Epson, which manufactures the NTSC TV projectors formerly marketed in the United States under the Kodak name, has developed such a projector.

In this projector, the HDTV image is created on three active-matrix polysilicon thin film transfer (TFT)-liquid crystal light valves 2-3 inches in diagonal (one each for the colors red, green, and blue) and projected onto a screen using a halogen lamp and only one projection lens, as shown in Figure 2.7.

The active-matrix liquid crystal projector offers several advantages over the CRT projector systems: single projecting lens, highly efficient light source, smaller assembly size, and lower cost. The LCD projector technology is not sufficiently developed to know yet whether the signal-to-light scattering noise (optical signal-to-noise throughput) or the luminous efficiency of the LCD projector will be better than those of the CRT projector; if so, this technology could well replace the CRT projector for both rear and front projection.

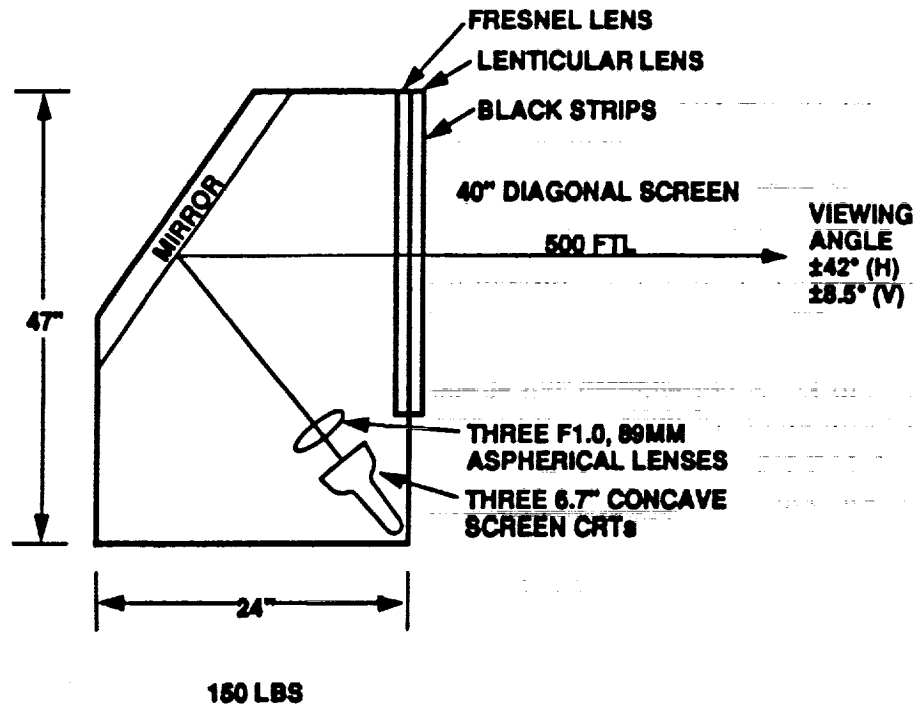
Matsushita, Sharp, and other Japanese firms are also developing active-matrix liquid crystal projectors in HDTV displays. MPT is encouraging LCD technology through a consortium about half the size, and in parallel to, the consortium organized by MITI for "Giant Electronics" that was tasked with developing large flat panel displays.

## **NEW SCREEN TECHNOLOGY FOR PROJECTION DISPLAYS**

### **Front Versus Rear Projection**

The projection CRTs and LCDs may be used in either front- or rear-projection applications; other issues determine the relative merits of the two types of projection. Front projectors use space more economically than rear projectors. The audience area is used for throw distance, and the screen is effectively a flat screen. However, the screen reflects the ambient light, which reduces the image contrast and dilutes the color purity. Also, the blocking of the image projection due to audience movement is an irritation.

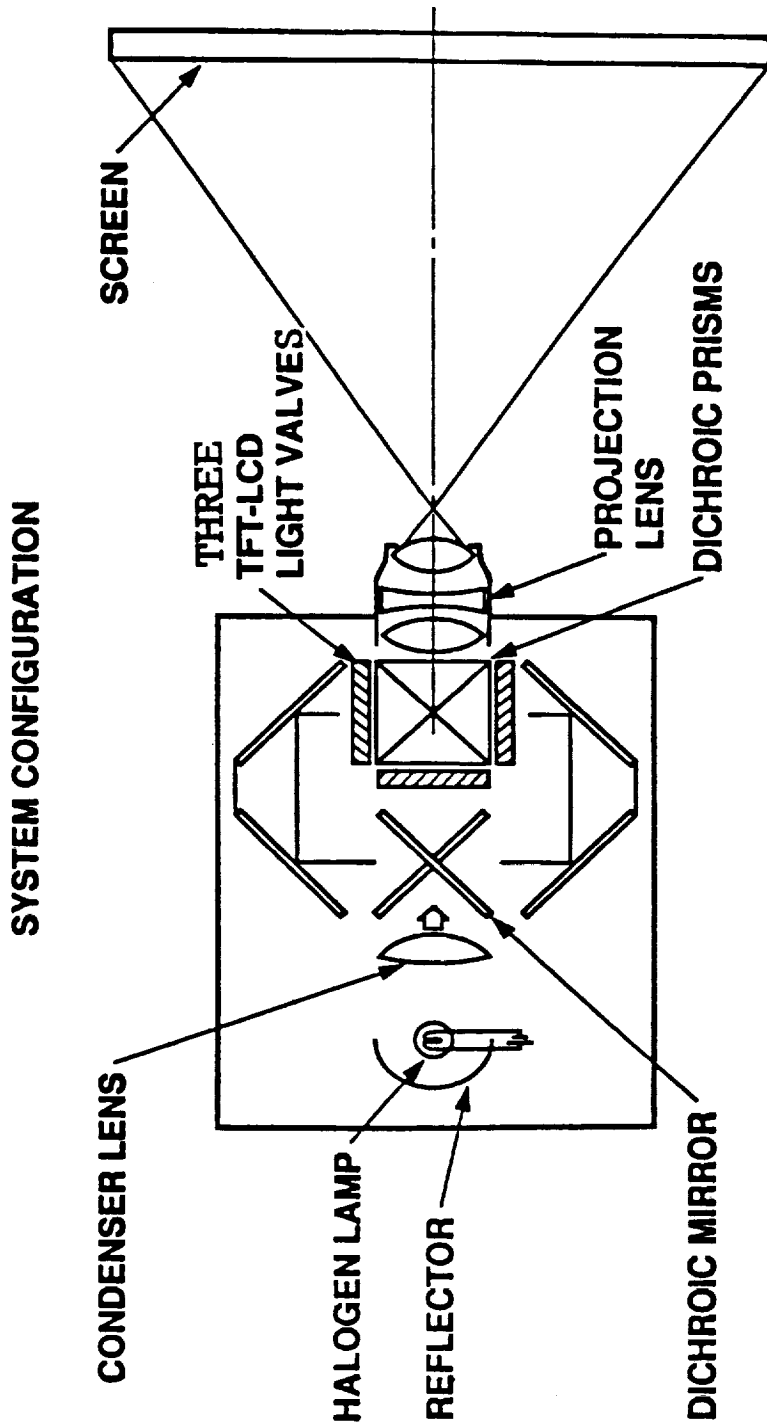
The rear projector throw distance is established in an area behind the screen, which can be minimized with folding mirrors and wide-angle lenses. The rear-



The baseline television set for HDTV will most likely be a three-tube rear projector cabinet similar to that available today for large screen television. According to our Hitachi hosts, the HDTV will sell for approximately \$3000 in the 1990s.

Figure 2.6. Example of a CRT Rear-Projection TV

Source: Handouts to the JTEC HDTV panel by Hitachi.



The single-lens-type active-matrix liquid crystal projector developed by Seiko-Epson shown here has obvious economies over the three-lens systems used in CRT projectors. The image is created on three active-matrix polysilicon thin film transistor (TFT)-liquid crystal display (LCD) light valves. One light valve is used for each of the colors, red, green, and blue.

Figure 2.7. Active-Matrix LC Projector

Source: Mr. Shunji Morozumi, Manager, Seiko-Epson Corp.

projected image is never blocked by the audience. The major advantage in rear projection, however, is realized through the transparency of the rear-projection screen. The ambient illumination is not reflected, but rather transmitted through the rear projection screen and trapped behind the screen.

### **The Rear-Projection Screen**

Hitachi and other firms have developed an innovative screen type for use with HDTV rear projectors. This screen is itself a complex optical system (See Figure 2.8), comprised of two plastic sheets. A Fresnel lens comprising the entire rear sheet collimates the diverging image rays in order to avoid a bright area near the center of the screen. A lenticular lens formed from columns of vertical cylindrical microlenses are molded onto both the view side and the projector side of the front sheet. The lenses on the projection side spread the image horizontally to fit the viewing angle of the audience; the lenses on the view side of the screen color-correct the lenticular micro lenses on the rear surface. Diffuser particles in the lenticular lens transparent material scatter light appropriately for a wide vertical viewing angle. Black stripes are placed on the screen front, over the cylindrical micro lens junctions, to prevent the scattering at the junctions from reaching the audience and to further minimize reflections of ambient light. The Fresnel grooves and lenticular micro lenses are made on a submillimeter pitch.

The new rear projector screens are a great advancement, since the room lighting can now be quite high without washing out the image on the screen. The concept is independent of the type of rear projector, and would work equally well with CRT and LCD systems.

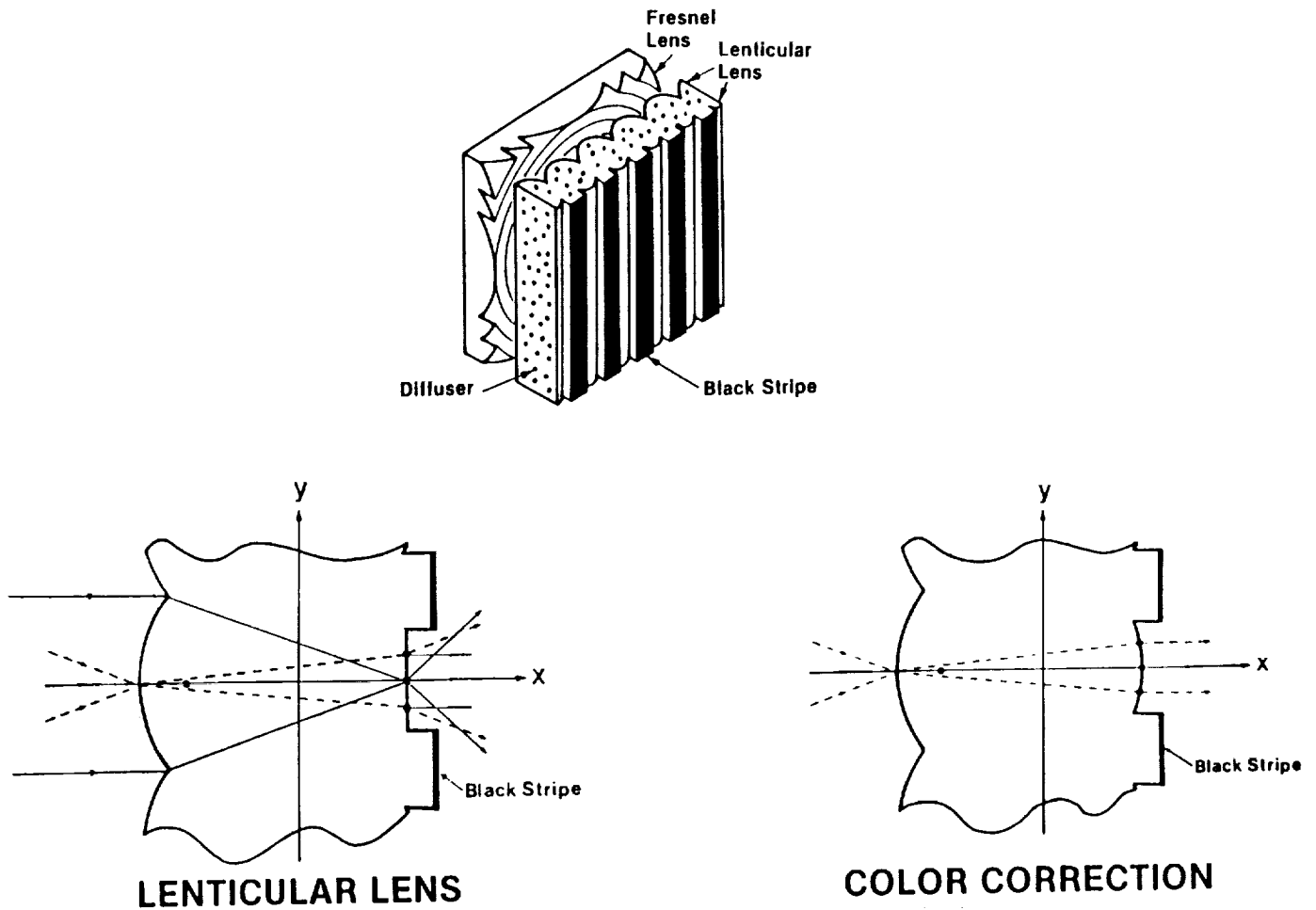
### **FLAT PANEL DISPLAYS**

Although flat panel display technology is less mature than the CRT display technologies described above, the Japanese are investing a great deal of money in flat panel R&D. Flat panel displays are expected to be the HDTV display standard of the future but have a long way to go to achieve the technical capability.

Flat panel displays are thin in cross-section, with a flat front surface, rather than the curved front surface of a CRT. They are also direct-view, as opposed to projection, displays.

#### **Goals for Flat Panel Research**

The primary reason for developing flat panel displays for HDTV is to reduce set volume, so that they can be shipped, used and stored, and mounted more easily than the bulky CRTs. This has long been a promoted objective of the displays



The rear projection screen is an optical element made up of two large plastic sheets. The Fresnel lens comprising the rear sheet is used to eliminate the hot spot by causing the diverging image to be collimated in the direction of the audience. The lenticular lens controls the horizontal viewing angle. The embedded diffusers control the vertical viewing angle. The black stripes prevent scattering at the apex of the microlenses making up the lenticular lens from reaching the audience and prevent the reflection of ambient lighting. Color correction is provided by micro-lenses on the front of the screen.

Figure 2.8. Rear-Projection HDTV Screen

industry, dating back to the 1960s quest by former RCA to develop a TV that could be hung on the wall like a picture.

The issue of HDTV set volume is an important one, particularly in Japan. Land in Tokyo may sell for up to \$20,000 a square foot, and apartments there can rent for \$20 a square foot per month. If the rear-projecting CRT display occupies six square feet, rental cost for the space alone may be \$120 a month. Typical Japanese homes and apartments are very small; consumers naturally voice alarm when the size of an HDTV projecting CRT display is described.

A second reason for developing flat panel displays is to dispense with the need for projection systems which are costly, delicate, and need to be properly aligned in order to achieve their potential for picture and color quality. Flat panel displays are direct-view systems. That is, the image is created electronically directly on the viewing surface, without the need for lens systems for projection.

### **Flat Panel Display Types**

While there are several different types of technologies which may be possible for flat panel displays (see Table 2.1), only two types are being pursued seriously in Japan for application to HDTV. These are the gas discharge or plasma panel display, and the active-matrix LCD types. The JTEC panelists saw examples of both types: NHK's gas discharge display, and Toshiba's active-matrix LCDs.

NHK has developed a 20-inch gas discharge flat plasma panel display (see Figure 2.9), which lags considerably behind projecting CRTs in resolution, brightness, and luminous efficiency, as shown in the following comparison:

<u>CRTs</u>	<u>PROJECTING FLAT PANEL</u>	<u>GAS DISCHARGE</u>
Size (inches)	40-300	20
Resolution	HDTV	NTSC
Brightness (ftL)	100	17
Luminous Efficiency (lumens/watt)	7	0.13

NHK has developed a 33-inch gas discharge flat plasma panel display, and NHK researchers expect to have developed a 50-inch gas discharge breadboard with HDTV resolution within about three years.

IBM/Toshiba and Sharp have both made 14-inch active-matrix liquid crystal flat panel color displays at NTSC resolution with a luminous efficiency of about two lumens per watt. A new family of manufacturing machines must be made before the LCD flat panel can be made any larger.

Despite ongoing efforts, no company has yet approached the size, color, and resolution needed for HDTV in a flat panel display. Although the flat panel design types described above can be used for computer monitors and NTSC television, significant advances are needed not only in size and resolution, but also in brightness and luminous efficiency, before either type can be applied to high definition television.

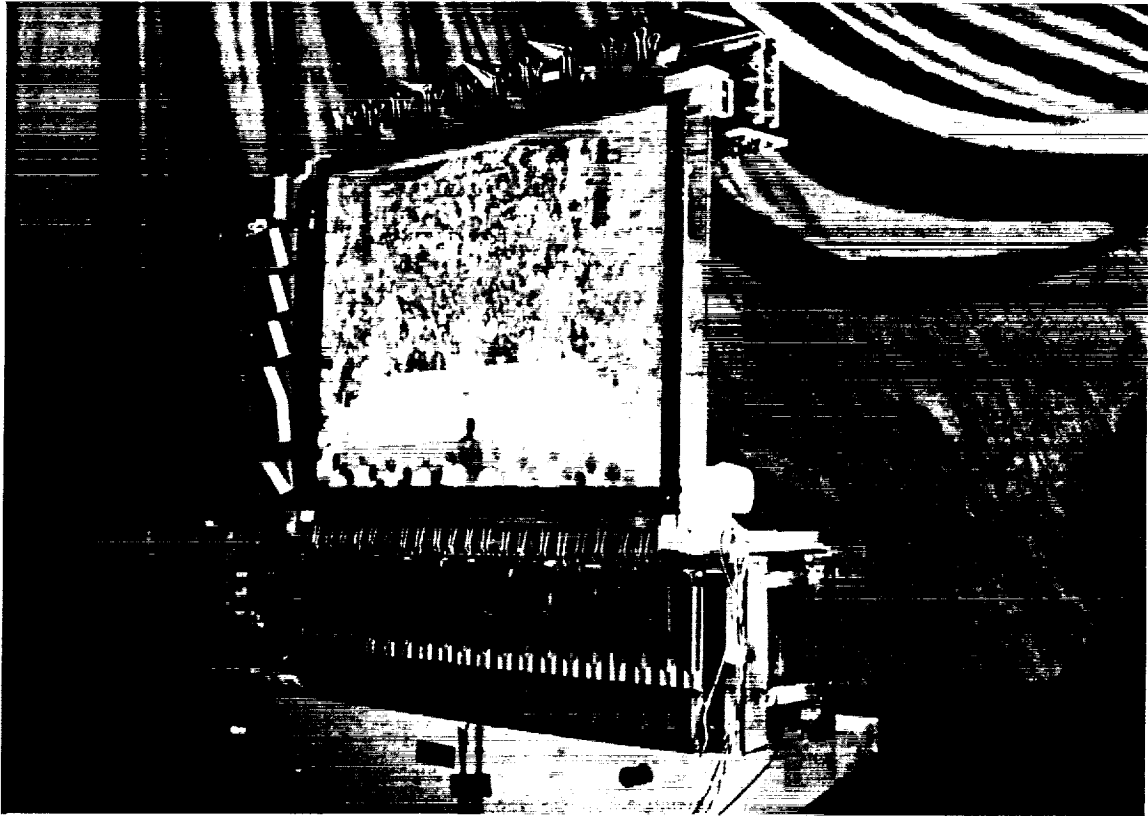
#### **Joint R&D for Flat Panel Displays**

NHK, MPT, and MITI have identified the lack of a large flat panel display for HDTV and other "New Media" as a critical technology issue. To solve this deficiency MITI announced the creation of the "Giant Electronic Concept" (GEC) or "Giant Technology Project" consortium in the Fall of 1989 to promote the development of a one-meter square active-matrix color LCD breadboard by 1995. This aggressive goal has since been modified to promoting research on crucial elements necessary before such a display can be attempted.

At present, the Japanese flat panel display industry is concentrating on NTSC TV and personal computer display applications. Several companies have announced significant facility investments totalling in excess of \$2 billion to build color active matrix LCDs. Sharp alone has announced the commitment of \$700 million for new facilities. Considering the NHK and Giant Electronics timetables, it seems reasonable to expect that HDTV flat panel displays of good quality will be available after 1995 and before 2000.

#### **CURRENT APPLICATIONS OF HDTV DISPLAY TECHNOLOGY**

The first scheduled HDTV direct-satellite broadcast was made in Japan on June 3, 1989. The subject matter was a live fashion show from New York, showing the international potentials of this medium. The signal was relayed to the U.S. by an NHK satellite. The project was considered by NHK to be an HDTV promotion and was viewed at approximately 90 demonstration sites throughout Japan. MITI and MPT are encouraging the implementation of about 150 demonstration sites in



**448 × 640 SUB PIXELS (NTSC)**  
**17 FTL**  
**0.131 M/WATT**

Researchers at NHK have been developing flat panel display technologies for HDTV. The most mature flat panel technology is shown here. Over the next three years, NHK plans to develop a 50-inch HDTV version extending this technology in both size and resolution. Major problems still exist with all flat panel technologies in brightness, luminous efficiency, and size.

Figure 2.9. NHK's Gas Discharge Flat Panel Display

Source: Courtesy of NHK

Japanese department stores and public centers. Such a site is shown in Figure 2.10.

The HDTV at this site is manufactured by Toshiba, and the complete system is outlined in Figure 2.11. Toshiba has offered this system for sale at \$1.1 million with an eight month delivery. This system is very versatile as it can receive inputs from satellite broadcast, tape, or laser disk, all under computer control. NHK sees that the value in the demonstration sites is to educate and to promote interest in HDTV. The department stores envision using the HDTVs to create customer interest in the store and its products.

HDTV theaters are also being demonstrated in Japan. Hitachi has developed a one-inch wide video tape HDTV system, which it demonstrated at Yokohama EXPO '89. In order for each of the two 25-foot diagonal exhibition screens to show a very bright image, four sets of three-CRT unit projectors (12 CRTs) were used for each screen (see Figure 2.12).

### **Computer Monitors Using High Definition Displays**

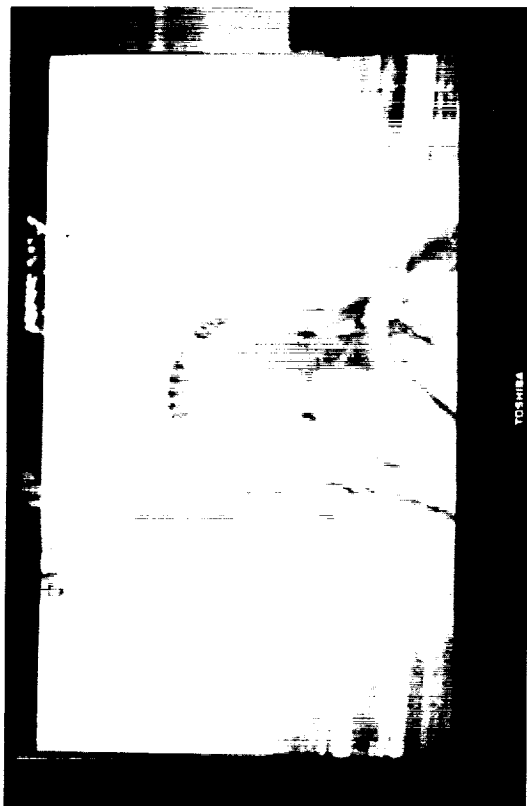
The application resolution of HDTV displays is comparable to current computer monitors, so that the two applications are converging. The high-resolution computer graphics monitors are at an actual resolution of 1024 horizontal lines by 1280 vertical lines and higher. The resolution of 1125/60 HDTV is at 1035 horizontal lines. The computer state of the art is such that the computer is now being used for generating, merging, and editing HDTV as well as NTSC images.

### **Educational and Museum Use of HDTV Baseband**

HDTV technology has been applied in an art gallery at Gifu, pictured in Figure 2.13. Visitors select the art to be viewed from the laser CD library of art, and then view it on HDTV direct-view CRTs.

In many respects, this type of art museum is better than a museum with actual art. The full gamut of an artist's works are shown in time sequence of the actual painting. The sequence is narrated by an expert with comments on the artist's life and the maturity of his skills. Closeups are shown of key sections of each painting to make specific points about brush strokes, techniques, etc. This could not be done with NTSC TV, because the resolution of NTSC is not capable of showing a masterpiece in sufficient resolution for the normal viewing distances used in museums or as suggested by the artist.

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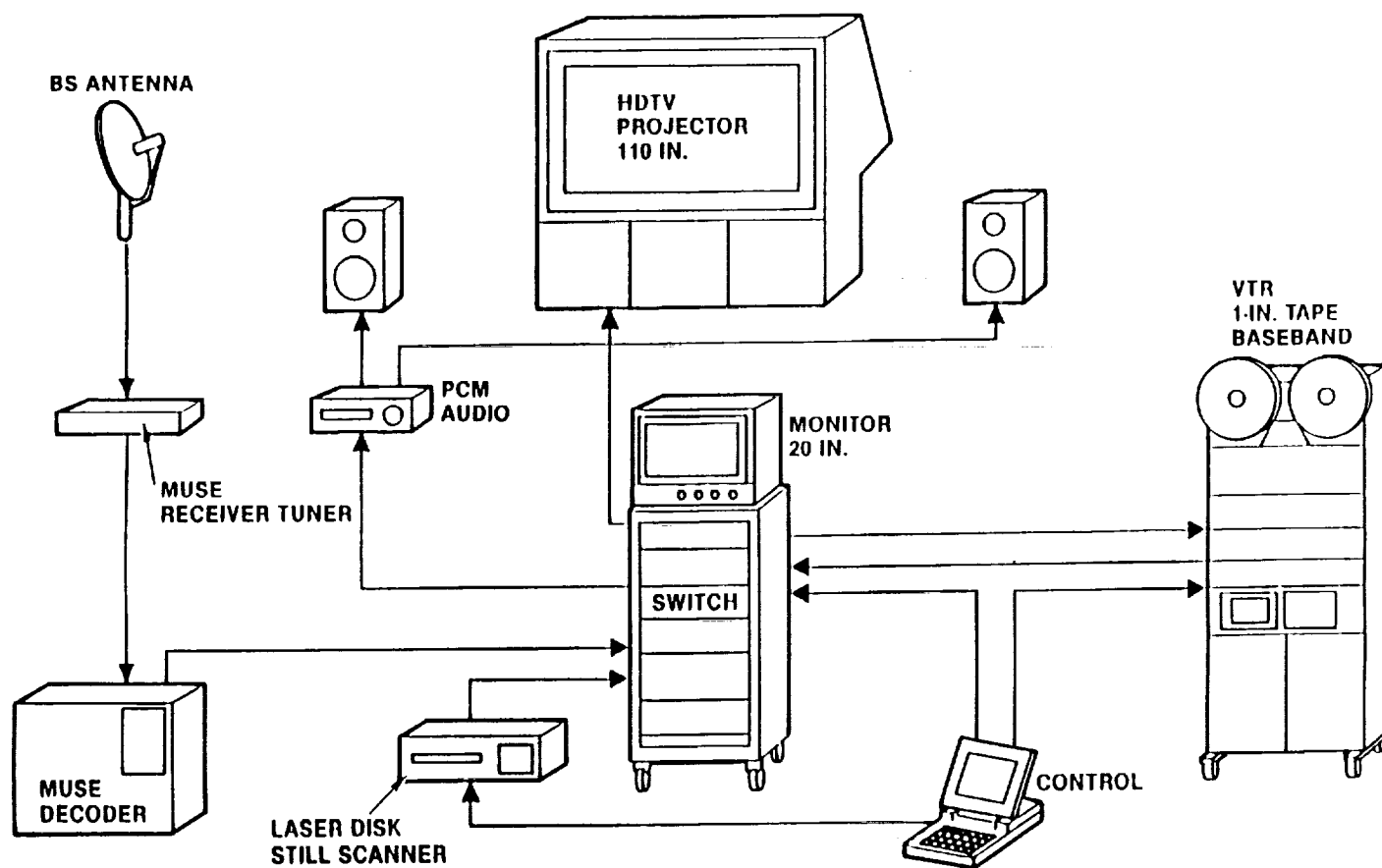
**TOSHIBA SYSTEM  
110 IN. REAR PROJECTION TV  
SOURCE MATERIAL, DBS/MUSE-E**



**HANKYU DEPARTMENT STORE  
YURAKUCHO STATION  
SOURCE MATERIAL, 1 IN. TAPE**

One hundred fifty promotional stations for HDTV are being established throughout Japan, typically using rear projection displays. They are located in prominent department stores and centers to give the Japanese public its first look at the quality and merits of HDTV.

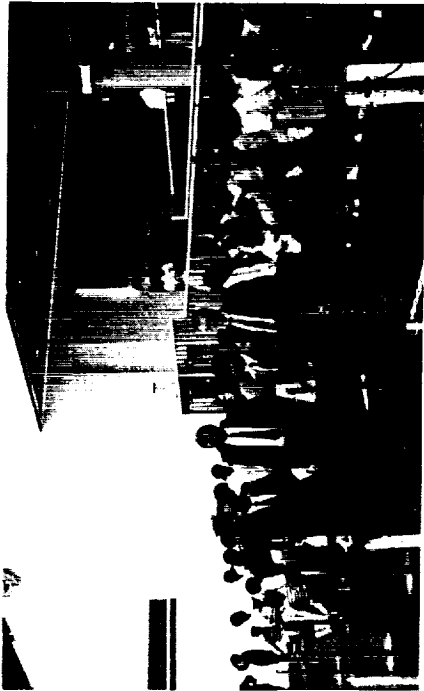
**Figure 2.10. First DBS Broadcast of HDTV, June 3, 1989**



The system shown in the Hankyu Department Store (Figure 2.11) was developed by Toshiba. The system is capable of displaying HDTV via direct satellite broadcast, laser disc images, or high-quality baseband VTR source.

Figure 2.11. Toshiba HDTV System

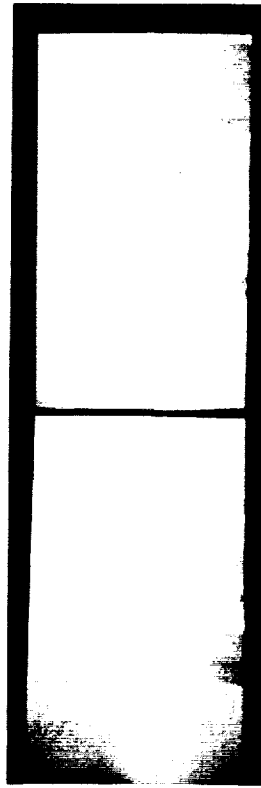
Source: Derived from Toshiba product literature.



HITACHI HALL

1 IN. DIGITAL VTR  
1400 MHz

HDTV SCREENS  
TWO 25 FEET, REAR PROJECTORS  
FOUR PROJECTORS PER SCREEN



Theatre-size HDTV screens can be made bright by using multiple three-tube projector modules. The Hitachi 25-foot screen at the Yokohama 1989 EXPO used four such modules per screen.

Figure 2.12. Hitachi's 25-foot HDTV Screens at EXPO '89



An example of direct-view CRTs is provided at the Museum of Fine Arts in Gifu, Japan. Still images of fine art from around the world are recorded on digital laser compact discs. The image is then shown in HDTV quality in a museum environment.

Figure 2.13. Hi-Vision Gallery, Gifu

Source: Museum of Fine Arts (Gifu, Japan) brochure.

### Hardcopy Color Images

Hitachi has developed a hard color printer which can restructure A4 size hardcopies from electronic HDTV images (either on television or computer monitor). The printed image is of HDTV resolution, as shown in Figure 2.14, with six pixels/mm, 64 shades of color, and 1024 x 1500 pixels. The HDTV image is loaded into a computer memory, processed or annotated as desired, and then printed using a dye-diffusion thermal transfer process as shown in Figure 2.15. A colored inked sheet as wide as the print, like wide typewriter ribbons, with each color dye primary in sequential areas, carries the dye to the paper in three passes --one for each primary color. At each pass, the dye is thermally transferred and diffused into special paper. Each primary color image could be transferred to separate paper or mattes, making color separation sets for a color printing industry press.

When the HDTV print of Figure 2.14 is viewed at a normal viewing distance, it looks as good as a photographic print. However, when viewed closely, or with a low-power magnifying glass, the pixel structure can be seen, as would be expected from the image pixel resolution described above. In this aspect, as with all electronic printing, the resolution is less than that of a photograph.

### CONCLUSIONS

The most impressive improvement in mass imaging products since the development of color television is coming into focus in Japan. The significance of HDTV is not so much due to its improvement in resolution over current TV, but because it will combine various electronics, communications, and information industries through an electronic medium with a common format standard where computers can be used extensively to edit, compose, and create in the process. The end product will have the distribution flexibility of television, the image quality of motion pictures, and nearly the hardcopy quality of photography.

Up to this time, the technical limitation has primarily been in the display. The five problems have been to (1) generate the resolution in one continuous image plane; (2) make the image plane large to create realism; (3) change images to show realtime dynamics; (4) create the image in color; and (5) combine all these features at a consumer market cost with acceptable weight, power, and volume characteristics. Many display technologies can meet several of these requirements --for example ac plasma panels can be made large with high resolution, but not simultaneously in color or with acceptable cost.

Some people feel that HDTV requires a large flat panel, direct-view display. Clearly, Japanese industry agrees, since it is pressing forward despite the fact that such a device is simply not available at this time. It may be possible by the year

2000. American industry still does not even have an NTSC TV flat panel display to hang on the wall, but it is close.

The HDTV display has come about from improvements in CRT basic technology, use of high-performance projection lenses optimally coupled to the CRT, and improvements in the projection screen, particularly the rear projection screens. The classical industrial electronic projectors, such as Eidophor and GE light valves using an oil film and Schlieren optics, are definitely challenged in the marketplace by the new Japanese CRT projectors.

The second contender for consumer HDTV displays is the LCD light valve using three active-matrix liquid crystal cells. It remains to be seen if this technology can be competitive with the CRT projectors. The CRT will always have a significant volume associated with the tube itself, and the displays industry will always try to improve upon this aspect with a flat panel technology.

After having visited the major Japanese companies, it has become vividly clear that the realization of HDTV will no longer be delayed due to the lack of a display technology. The CRT projector displays can meet the five requirements listed above.

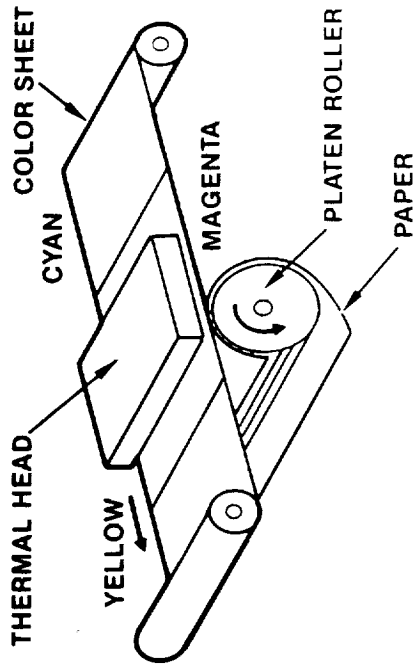


Color hardcopy of HDTV images has been developed and is fully capable of replicating the high-resolution electronic image.

Figure 2.14. Hitachi A4 Print

Source: Hitachi printed this for the panel.

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## DYE DIFFUSION THERMAL TRANSFER



The image can be modified by a conventional computer before reducing to hardcopy. The dye diffusion thermal transfer process gives a very high-quality image comparable to a photographic print available in the consumer market.

Figure 2.15. Hitachi A4 Color Video Printer

Source: Derived from Hitachi literature.

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2. This goal is part of a 5-point program described by the Electronics Industry Association of Japan in promotional literature at the Japan Electronics Show, Tokyo, 1988; also, Takeshi Kido and Tatsuhiko Kondo, "Putting HDTV to Practical Use Has Become a Realistic Target," JEE (March 1989):30-35.
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4. Lawrence E. Tannas, Jr., *Flat-Panel Displays and CRTs*, (New York: Van Nostrand Reinhold, 1985), Chapter 1.
5. Takashi Fujio, "High-Definition Television Systems," Proceedings of IEEE, 73, no. 4 (April 1985):646-55.
6. Toyohiko Hatada et al., "Psychophysical Experiments on a Wide-Field Display," NHK Laboratories Note, Serial No. 276 (July 1982).
7. Every intersection of a horizontal and vertical line is potentially a pixel. Total pixels may be expressed as the product of the number of vertical and horizontal lines. As various factors will affect the actual number of pixels, this is only an approximate figure. Estimates of the increase in number of pixels from NTSC to HDTV vary from four times to eight times. See also the following sources: Shinichi Makino, "Development of High-Definition TV Systems in Present-Day Japan," JEE (March 1987):28-30; DIAJ Primary literature describing HDTV vs. NTSC at the EIAJ HDTV Exhibit Booth, Japan Electronics Show, Tokyo, October 1988; Toshiaki Hioki et al., "Hi-Vision Optical Video Disc", IEEE Trans. on Consumer Elec., 34, no.1 (February 1988):72-77.
8. Other similar CRT displays are described in the following: Masahiro Kawashima et al., "Display and Projection Devices for HDTV," IEEE Trans. on Consumer Elect. 34, no. 1 (February 1988):100-9; K. Ando et al, "A 54-inch High-Contrast High-Brightness Rear-Projection Display for HDTV," SID Proceedings, 26/4 (1985):315-321; S. Ashizaki et al., "Direct View and Projection CRTs for HDTV," IEEE Trans. on Consumer Elect., 34, no. 1 (February 1988):91-99.

## **CHAPTER 3**

# **HIGH DEFINITION STANDARDS AND EQUIPMENT DEVELOPMENT IN JAPAN**

Birney D. Dayton

### **INTRODUCTION**

The development of high definition television in Japan has raised the awareness of many Americans about the rate at which Japan's technology is advancing. Manufacturing competitiveness issues have garnered the most attention, but the ultimate effect on the U.S. position in program production may be extremely important as well. The United States currently has a dominant position in program production in the world market. The effort to introduce HDTV as a program distribution method has met with some resistance from the program production community. Producers of 35-mm feature films are the logical source of early HDTV programming. However, many of them feel that HDTV is close enough to "vault quality" that they will have nothing left to sell if an HDTV duplication capability is available to the consumer.

A similar situation existed after the first attempts by Japanese manufacturers to introduce rotary digital audio tape (RDAT) machines into the U.S. market. A number of music distributors were fearful that the capability of the RDAT to exactly duplicate the data on a compact disc (CD) would impact the market for CDs through illegal copying. CBS Records was the loudest protester. Shortly thereafter, Sony Corporation purchased CBS Records. Whether silencing the

opposition to RDAT was one of the objectives of the purchase is not clear. The fact remains that RDAT has now been accepted into the U.S. with the addition of a copy protection scheme that is unlikely to prove any more robust than the many far more sophisticated schemes that were tried and broken in the personal computer market. The successful deployment of HDTV video cassette recorders (VCRs) depends on the availability of premium program material, such as the movie library of a major Hollywood studio. Sony's recent purchase of Columbia Pictures will provide such a library. Japan Victor Company (JVC) has recently invested \$100 million into the production of new movies. Such acquisitions and investments will give Japanese VCR manufacturers access to film libraries with which to promote new equipment standards.

Behind the copyright issues relative to RDAT and HDTV is a deeper and broader issue. At the present rate of technological progress, digital techniques will dominate virtually all forms of human communication by the end of this century. Some examples include encyclopedias, dictionaries, and other reference works that are already available on CD-ROM (compact disk read only memory). In addition, works of art, including films, paintings, music, and even three-dimensional objects such as sculptures, can be digitized. Once digitized, a creation can be exactly reproduced as many times as desired. Computer software was the first type of intellectual property to be affected, but it will not be the last. The subsequent RDAT controversy demonstrates that it will be almost impossible to stop the march of technology.

We need to examine the fundamental nature of the copyright process and find new ways to compensate writers, artists, and other creators if we are to avoid a crisis. A key point is that Japan is the world leader in the manufacture and distribution of low-cost (mass marketable) digital communications equipment such as CDs, RDATs, and recordable optical disks. In the next decade, Japan will deliver digital HDTV on tape (probably optical), and the enormous data storage capability that implies, as well as high-resolution color laser printers and other means of reproduction. The potential for conflict between Japanese manufacturers and the creative community worldwide is quite high. This issue will be aggravated further by ongoing developments in data compression as represented by Intel's work in digital video interactive (DVI) (Ref. 3.1) and General Instrument's recent proposal to the FCC for digital HDTV (Ref. 3.2). At the compression factors proposed, two hours of theater quality HDTV could be recorded on an 8-mm videotape cartridge with little or no change in recording density from Japan's current machines.

While visiting with manufacturers in Japan, JTEC panelists heard one statement many times: "We can build to any standard very soon after we know what it is." Depending on the manufacturer and the product in question, "very soon" was identified to be between one and two years. The key here is that the

pioneering work of Japanese companies in HDTV development and subsequent early standardization has not channeled their thinking so narrowly as to inhibit their participation in different systems abroad. On the contrary, they have built a technology base that will allow them to respond very quickly to real equipment requirements that develop after standardization occurs in the U.S. or any other country.

In the meantime, many 1125/60 products have been developed or are under development in Japan. These products are already starting to show up in the U.S. industrial and military markets where standardization is less important than in the broadcast market. These early sales help to amortize the investment made by Japanese manufacturers and to move them down the learning curve towards low-cost HDTV consumer products.

### **HDTV AND EDTV STANDARDS DEVELOPMENT**

Although the development of standards in Japan and in the U.S. is a similar process, there are many differences. Japanese companies have been participating in the U.S. process, directly or through proxies. This is possible largely because many Japanese speak English, and the diverse nature of American culture makes it very easy to find proxies either for hire or who simply see an opportunity for themselves in assisting a Japanese position. On the other hand, relatively few American engineers or executives speak Japanese. The result is that American companies are often distant from the standards process in Japan.

Another difference is the strong export orientation of Japanese companies. If they can influence our standards to their advantage, they will. Many American companies, on the other hand, have shown little interest in designing to the Japanese market (e.g., General Motors, which tried to sell left-hand drive cars in Japan). Those who have tried have often encountered obstacles: Zenith tried to sell TV sets in Japan and met organized resistance in the distribution channel (Ref. 3.3). Some, however, have been successful and have been active participants in the Japanese standards process. Motorola dominates cellular radio, even in Japan, and IBM is very successful in computers.

From the outside looking in, the standards process in Japan appears to be a very dynamic process. A rapid cycle of standardization, manufacture, improvement, adaptation, and restandardization is evident. An example of this process can be seen in the evolution of the VHS tape format from VHS to VHS HI-FI to VHS HQ to SVHS. A similar evolution has occurred in the BETA format as well as 8-mm video (now HI-8 is available) and RDAT (DATA-DAT for computer data storage is the latest adaptation).

Japanese companies have a much lower resistance to the NIH (not invented here) factor than is prevalent in their U.S. counterparts. This difference is likely due to Japan's "export or die" philosophy of business. Japanese companies will adopt standards from elsewhere, if they fit, and improve and adapt them to suit changing needs. Some examples can be seen in cassette audio (originally developed by Philips). The initial purpose of the cassette was voice recording and low-end entertainment. With the addition of better tape and the licensing of Dolby noise reduction (another case of low NIH resistance) the once humble Philips cassette has completely replaced reel-to-reel audio tape in the consumer market. Compact Disc (developed by Philips) and Laser Disc (developed by Magnavox) are some other examples of borrowed standards that the Japanese manufacturers have improved and adapted.

In contrast, the standards generation process in the United States is often very sluggish. We tend to set up due process committees that debate for years before coming to a conclusion. When a conclusion is finally reached, the resulting standard is cast in stone, if it has not already been preempted by a de-facto standard from one manufacturer (U.S. or foreign). In recent years, more and more of our television equipment standards (particularly consumer equipment) have been determined by mass import after standardization in Japan. Examples include BetaCam and M2 production video recorders and all consumer VCRs, including their interfaces such as the "S connector" on TV sets for SVHS recorders and the optical digital interface between CDs and RDATs. These items were developed, standardized, and built in volume in Japan before being exported. After export began, designs were adapted to suit U.S. market needs.

Several underlying reasons for Japan's relatively more aggressive approach to standardization can be identified. The emphasis on exports is certainly one: with clear standards for equipment, a commodity-oriented manufacturer (as most Japanese companies are) is in a better position to compete (Ref. 3.4). Another factor is Japan's long-term view, coupled with its low cost of capital. Japanese companies are willing to make the investments necessary to keep up with a dynamic standards environment. With our relatively high capital cost (and often less adaptive plants), U.S. manufacturers are more sensitive to standards changes than Japanese companies. A key factor in Japan's standards approach both domestically and abroad is strong government participation. MITI, MPT, and NHK have all played prominent roles in the standardization of HDTV in Japan and in the effort to promote the Japanese standard on a worldwide basis.

Numerous standards for different HDTV (1125/60) equipment have been developed or are under development in Japan. The most significant point about the work Japanese companies have done to develop 1125/60 equipment is that

the technology developed is readily transferable to other standards. Whatever standard is chosen for terrestrial broadcast of advanced television in the U.S., Japan's manufacturers will be well positioned to lead the way in production equipment as well as consumer equipment.

To avoid confusion, throughout this chapter, a "standard" is defined as compatible equipment made by more than one manufacturer. There are a number of different categories of HDTV standards. Some are well defined, and others are still in development. However, throughout the standards definition and development process, one position stands out clearly: in Japan, HDTV (defined as 1125/60) is always presumed to be incompatible with terrestrial broadcast. This incompatibility has caused a reaction from the independent broadcasters and resulted in the development of extended definition television (EDTV) approaches. The following paragraphs will attempt to quantify the present state of HDTV (and EDTV) standards development in Japan.

### **Production Standards**

*Video Interface.* Standards currently exist in Japan for HDTV (1125/60) video interfaces in both the analog and digital domains. The development of these specifications has proceeded in conjunction with the work of the Society of Motion Picture and Television Engineers (SMPTE) in the United States. The analog interface is more completely specified than the digital interface, but equipment from multiple manufacturers exists in both cases. The 1125/60 standard defines an interlace scanned system. Interlace scan was developed in the 1930s to minimize flicker and visibility of the scanning raster in an analog system while keeping bandwidth down. In today's world of digital processing and frame memories, interlace scanning is not an efficient solution to bandwidth reduction, and in the limit inhibits several kinds of signal processing, including standards conversion and bandwidth reduction (Ref. 3.5).

NHK, supported by several Japanese manufacturers, has expended tremendous effort to gain acceptance of 1125/60 as a common world production standard. That effort has been substantially thwarted by the European Eureka 95 project and its 1250/50 HDTV proposal. In the absence of a common world standard, conversions between HDTV standards will be necessary, as well as down conversion to existing systems. The 1125/60 system will suffer substantial quality loss in conversion due to its interlaced scanning and the tradeoffs necessary for the system to have an analog interface.

*Tape Recording Formats.* At this point, two different types of studio tape recorders have been built for the 1125/60 system. The first is a 1-inch helical scan analog machine. The second is a 1-inch helical scan digital machine which records data at 1.2 gigabits/sec (Gb/s). Sony has been the leading

supplier of both machines, but while in Japan, the JTEC team also saw machines of both types from Hitachi. At this point, the tape formats for both types of recorder are standardized in Japan. A second generation of digital HDTV production recorder based (most likely) on a 19-mm cassette tape transport is under development, but has not been shown (Ref. 3.6).

The 1.2 Gb/s recorder is the highest rate commercially available data recorder in the world by a factor of five. The applications for such a machine outside the HDTV arena are numerous. Full motion medical imaging and synthetic aperture radar are only two of the obvious applications for such a recording capability. When the cassette version becomes available, this high-rate recording capability will surely find application outside of HDTV and may well act as a wedge to open new markets for the Japanese companies which have developed it. This demonstrates HDTV as a technology driver, since its requirements have caused the development of a general purpose capability that is unique in the world.

*DBS Standards.* The 1125/60 system has been proposed for direct broadcast satellite application for many years. Early experiments with full-bandwidth transmission led NHK to the development of the MUSE (Multiple Sub-nyquist sampling Encoding) system of video compression in order to conserve satellite bandwidth. This technique is used in NHK's current daily satellite broadcasts of HDTV programming. It is notable that the assumption of terrestrial incompatibility associated with HDTV has created a perceived need for a satellite industry in Japan. The first DBS satellite in Japan was purchased from a U.S. vendor, and two of three transponders failed shortly after deployment. As a consequence, Japan has developed a complete satellite manufacturing and launching capability that is likely to compete aggressively in the world satellite market. This is a good example of how Japan's government and industry working together have used the HDTV banner to create a drive for the development of technology that is truly far afield from the basics of electronic imaging and display.

#### *Industrial Standards.*

Tape Recorders/Players. Two types of cassette-based HDTV tape machines have been standardized in Japan for the industrial market. Both use 1/2-inch cassettes that have also been standardized. One is a baseband analog recorder that works on principles similar to the 1-inch analog production recorder mentioned above. This unit can record and playback 65 minutes of 1125/60 material on one cassette, and is currently manufactured by most of the companies visited by the JTEC panel. Matsushita, Sony, and Hitachi have been advertising this type of machine for about two years. The second type of tape machine that has been standardized is the MUSE VCR. This machine was

developed by NHK and can record and play material encoded in the MUSE format. Since the MUSE encoder is much more complex than the decoder, this machine will not easily grow into a recorder of camera video. However, the baseband recorder described above could evolve into a camcorder in time.

Optical Disk Players/Recorders. Standardized optical disk players using the MUSE signal format are being made by many Japanese manufacturers. Several are making baseband optical players for industrial use. So far, an optical HDTV disk recorder has not been shown.

Other Likely HDTV Standards. Work is currently underway in Japan to develop a digital HDTV recorder using digital image compression techniques. This work may well dovetail with similar work at Nippon Telephone and Telegraph (NTT) to compress digital HDTV for fiber-optic transmission. While in Japan, members of the JTEC team were shown a compressor at NTT that yielded very high quality HDTV pictures at 100 Mb/s. Additional work is underway at NTT to develop an even higher performance compression algorithm.

The technology already exists in Japan to build a 100 Mb/s VCR (Ref. 3.7), so the standardization of a compression algorithm could cause a linking between VCRs and fiber. In addition, a digital compressor may well be cheaper and easier to implement than the complex scheme that is used in the baseband VCR mentioned above. A digital compression recorder may well turn out to be the basis for the most economical high-quality HDTV camcorder. The signal processing requirement for such a machine is very large (1-5 billion instructions/sec), but is all digital and minimizes the need for costly analog-to-digital and digital-to-analog conversions. Work in this area may have considerable spillover into other fields, since it has links to supercomputers, medical imaging, and radar. The development of digital video compression techniques for over-the-air transmission and satellite broadcasting in the U.S. (mentioned in the introduction to this chapter) certainly will not be lost on Japanese VCR manufacturers, and they may well be first to apply the principles in a deliverable product. This could be a digital HDTV version of a VHS recorder or an 8-mm recorder.

### **EDTV Standards**

While in Japan, the JTEC team also observed EDTV equipment operating at 525/59.94 progressive scan rates and producing both 4:3 and 16:9 aspect ratio pictures. This type of equipment was seen in several locations, with the most advanced demonstration being at Hitachi Central Research Labs. It is not clear how far along the standards are for progressive scan 525/59.94 production interfaces, but the Broadcast Television Association (BTA) is clearly sponsoring work in this area. The JTEC team observed wide-aspect, progressive-scan

cameras in operation, but saw no recorders. This will be an area to watch, since it represents the conflict between NHK's universal pursuit of 1125/60 and the cost considerations of the independent broadcasters in Japan. The terrestrial broadcasters in Japan have even less opportunity to engage in HDTV broadcasting than U.S. broadcasters, since there is virtually no unused spectrum in Japan. Japanese broadcasters do not have the "simulcast option" or the "augmentation channel option" available to them, and must make do with a single-channel, receiver-compatible solution for advanced television (ATV). Sony displayed a sign in its booth at the National Association of Broadcasters 1990 convention in Atlanta promoting an 8:4:4 (525 progressive) recording system, but no literature was available. At one point, BTA indicated it would submit a proposal to the FCC Advisory Committee for an EDTV system, but later backed out (presumably in the interest of harmony with NHK).

BTA has developed an EDTV-1 standard for terrestrial broadcasters in Japan which includes compatible improvements to an NTSC broadcast and a ghost canceler training signal to assist EDTV receivers in ghost suppression. Many Japanese broadcasters are already on the air with this standard, and sets are becoming available with ghost cancellation, noise reduction, and de-interlacing. These sets will all contain at least enough RAM for a video frame store. Work is also continuing on EDTV-2, which is intended to have a wide-aspect-ratio while remaining compatible with existing NTSC receivers. BTA showed a demonstration EDTV-2 system in the Advanced TV area at NAB 1990, and it made very clean pictures, but without the sharpness usually associated with HDTV.

EDTV-1 can be implemented at the production end with conventional equipment, but EDTV-2 will require wide-aspect ratio 16:9 progressive-scan sources for proper implementation. Cost considerations will encourage the development of a wide aspect ratio, progressive scan EDTV production system. Programs may be down-converted from 1125/60, but a wide-aspect-ratio, progressive-scan 525/59.94 production system would operate at less than half the bandwidth and cost.

### **NHK's Proposals for U.S. Broadcasters**

NHK has submitted four different ATV proposals to the FCC Advisory Committee for consideration. These are MUSE-E, Narrow MUSE, Compatible MUSE-6, and Compatible MUSE-9. Three of the proposals, Compatible MUSE-6, Compatible MUSE-9, and MUSE-E, have recently been dropped by NHK for consideration by the Advisory Committee, but Narrow MUSE is still in submission. This leaves NHK with only a simulcast proposal before the Advisory Committee.

## MANUFACTURING AND HDTV IN JAPAN

A Ministry of Posts and Telecommunications (MPT) brochure describes HDTV as "the cornerstone of the information age." This statement and many other similar ones indicate a dedication to the concept of HDTV in Japan. The purpose of this dedication seems to be to focus the Japanese electronics industry on a problem that, when solved, may well have advanced the state of the electronics manufacturing art in Japan a generation beyond the rest of the world. The effect has already been dramatic.

### Components

*HDTV and Semiconductors.* When the goal to make HDTV generally available was set, the technology of the day was not capable of the required performance at any price, and certainly not at consumer prices. The process technology that has been developed as a direct consequence of the HDTV goal is truly impressive. The current MUSE receiver electronics fits on a single circuit board containing 100 integrated circuits with about an equal number of custom and standard integrated circuits. The last generation required half a rack of electronics, and the next generation is expected to be a few chips. A MUSE receiver produces an output of over 50 million pixels per second from a subsampled input signal. The process requires on the order of a billion operations per second and several megabytes of very fast memory.

When the MUSE concept was proposed, the notion of such a complex computer as part of a consumer product was dismissed by most technologists in the U.S. In the few intervening years, Japan's integrated circuit capability has advanced dramatically to where in many areas it leads the world. To achieve the HDTV receiver goal at consumer prices, at least one more order of magnitude improvement in processing power per dollar and per watt will be required. At the present pace, that will happen in the next two to three years. The effect on the computer industry of such a processing capability will be to put Japan in a much more advantageous position in the computer market.

*Displays.* Japan is a dominant supplier of high resolution graphics displays. However, displays are still one of the weakest points in any HDTV deployment strategy. A wide viewing angle is necessary for full appreciation of an HDTV image. Given consumer viewing habits and typical living room and access door sizes, large-scale deployment of HDTV is dependent on low-cost flat panel displays. During the JTEC visit to Japan, many projection systems were demonstrated, as well as some large (and heavy) direct-view CRTs. High-performance flat panel displays were notably absent. One of the more promising technologies was shown at Matsushita's 70th anniversary technology demonstration in the spring of 1989. There, Matsushita demonstrated a flat

panel CRT technology that allowed several lines (6 at that time) to be addressed simultaneously. This approach provided full color, high brightness, high resolution, and high efficiency simultaneously in a display no more than a few inches thick. If such a display can be built successfully in large sizes, it may well be an answer to the HDTV display problem. Even if displays of this type cannot be successfully manufactured in sizes larger than 25 inches, the spinoff effect in computer workstations will be substantial. This is one more example of how Japan's focus on HDTV as a technology driver has produced a manufacturing capability that will result in leadership in other fields.

At the NAB 1990 Convention, Toshiba demonstrated two significant new devices, a CCD HDTV camera and a very bright display tube. The camera made very quiet pictures and was specified with 10 dB better signal-to-noise ratio than in tube cameras. Conversations with Toshiba officials indicate yields are still poor, but work on 2-megapixel CCDs is clearly moving ahead. The display was a 35-inch shadow mask CRT with very high brightness and an improved green phosphor that highlighted for the first time the improved color gamut agreed upon by SMPTE and BTA. The green phosphor was still short of the standard, but much improved. According to Toshiba representatives, this display was designed for mass production for consumer sets. Certainly it demonstrated adequate brightness for living room applications, and is as big a CRT as can fit in most Japanese homes.

*Mechanical Subassemblies.* The effort to develop HDTV recorders has already increased Japan's lead in magnetic tape recording, and will likely continue to do so. Products already on the market include 1.2 Gb/s digital tape recorders, and 1/2-inch analog tape recorders with nearly 30 MHz of total video bandwidth. Much of the head, tape, and servo technology required for these high-performance machines has already surfaced in the "High-8" VCRs introduced to the market in Japan over a year ago, and now being offered in the U.S. for professional use (Ref. 3.8). In the future, many more linked products can be expected in both consumer and industrial markets.

### **End-Use Products**

In addition to component and subassembly development, the HDTV effort in Japan has produced a daunting array of finished products. As the effort continues, more and different products will be announced. The following paragraphs list some of the currently available HDTV products from Japanese manufacturers, and some that can be expected in the next year or two.

## Studio HDTV Equipment

### Available Now

*High Sensitivity Cameras (tube pickup).* Sony sells cameras with in-house manufactured saticon tubes. Ikegami also sells saticon cameras, but also offers a HARP-tube camera. The HARP tube is a high-sensitivity avalanche target tube designed by NHK to improve low-light-level performance.

*Analog Tape Recorders.* Sony's first HDTV recorder was a 1-inch analog recorder, but is no longer available. Hitachi has also offers a similar machine. These four-track machines deliver 20 MHz of luminance bandwidth, time expanded and alternately recorded on two tracks. Two 10-MHz bandwidth chrominance channels are recorded on two more tracks.

*Digital Tape Recorders (reel-to-reel).* Sony's current offering is a 1-inch machine that records 1.2 Gb/s of digital video data with a rotating head, and concurrently records 8 channels of studio digital audio with a stationary head stack along the edge of the tape. This approach allows straightforward independent editing of audio and video.

*Production Switchers (analog).* Sony offers a small analog switcher.

*Digital Video Effects.* NEC made a DVE for the Tsukuba 1985 exposition, but has not offered it for sale in the U.S. Toshiba offered a digital effects unit for sale at the 1990 NAB show.

*Painting Systems.* At least one HDTV digital paint system is available from Japan. It is worth noting that the first digital HDTV paint system available was made by Quantel Ltd. in England. This unit was first shown at the 1985 Montreux exposition in Montreux, Switzerland. It has been in production since.

*Monitors.* A number of Japanese companies make direct-view cathode-ray tube monitors, including Sony, Ikegami, Toshiba, and Matsushita. The 40-inch Sony Trinitron has the highest resolution, and the 36-inch unit shown by Toshiba at NAB 1990 has by far the highest brightness.

*Projectors.* As with direct-view monitors, most manufacturers in Japan make HDTV projectors. They vary from 50 inches to over 200

inches, and have gotten progressively better each year. Several of the current models are comparable in brightness to 35-mm film projection, at least as shown in many theaters today.

### Expected Soon

*CCD Cameras.* Several manufacturers are developing CCD cameras, including Sony, Toshiba, and Hitachi. Toshiba showed a prototype at NAB 1990 that had a visibly better signal-to-noise ratio than tube cameras.

*Distribution Equipment.* Some distribution equipment is likely available in Japan, but Japanese manufacturers have offered very few products in the U.S. Some U.S. routing switcher manufacturers have offered wide-band routers and distribution amplifiers, but the list of available equipment is still short.

*Cassette Digital Tape Recorders.* An HDTV digital cassette tape recorder will likely be offered by some Japanese manufacturer in the next couple of years. Officials at Sony indicated that it is working on such a machine, but did not disclose the format. The 19-mm cassette currently used in the 525 line D-1 and D-2 recorders is a candidate with a new tape formulation.

*Digital Production Switchers.* Toshiba showed a prototype at NAB 1990.

## Transmission Equipment

### Available Now

*Fiber-Optic Digital Transmission Equipment.* Sony showed a 1.2 Gb/s fiber link at NAB 1989.

### Expected soon

*CATV Equipment.* Several companies including Matsushita and Sumitomo have begun offering broadband fiber products for the standard television cable market as cable companies try to modernize their plants to get ready for HDTV.

## Industrial Products

### Available now

*VCRs.* Several companies offer a 1/2-inch analog cassette recorder that was initially designed by NHK. The machine records 65 minutes of HDTV, and has 20 MHz of luminance bandwidth and 7 Mhz of color bandwidth. The color bandwidth is allocated to the color difference signals, R-Y, and B-Y on an alternate line basis, so the machine has reduced vertical color resolution, but this is not noticeable to the untrained eye.

*Optical Disk Players (MUSE and wideband).* Sony offers a wideband disk player, and several manufacturers offer MUSE players.

*Monitors.* The same monitors that are available for studio application are also available for industrial use, but are typically very expensive and not very bright. The first exception may be the unit demonstrated by Toshiba at NAB 1990. It was very bright, and when asked, Toshiba officials said it was targeted for mass production.

*Projectors.* Like direct-view monitors, HDTV projectors are quite expensive, and the studio systems are available for industrial use. Unlike direct-view monitors, projectors can make a very big picture and even at \$50,000 to \$200,000 and more, these units are finding homes in CAD display systems, military war boards, and other places where many people need to view the same picture simultaneously. As HDTV develops, large-screen projectors will likely be a key driver in the industrial and military markets.

*Graphic Art (Painting) Systems.* Again, the same systems are available as for studio, but here, the development was the other way around. The graphic arts industry's requirements drove the development of products that were later converted to studio production tools. This trend is likely to continue, since very high quality is needed in the magazine advertising business, and many of the same source matching problems as are encountered in film-to-video intercutting must be overcome daily.

### Available soon

*Cameras (and Camcorders).* As industrial applications mature and a larger volume market develops, lower cost cameras and even HDTV camcorders will surely be available from Japanese manufacturers.

## Consumer Products

### Available soon

*MUSE Receivers (rear projection).* When the JTEC team visited Japan, most manufacturers were planning to offer MUSE receivers in support of NHK's satellite broadcasting schedule. It is not clear when these receivers will be truly priced as a consumer product.

*MUSE VCRs (for precompressed signals only).* We saw several VCRs identified as MUSE units. It was not clear whether they were intended to be playback-only units for MUSE prerecorded tapes, or whether they would be capable of recording MUSE broadcasts. What was clear was that they would not record uncompressed camera video, and therefore would not serve as part of a camera/recorder package. Since little or no work has been done on reducing the cost of the MUSE encoder, these recorders are likely not on the critical path to a camcorder solution.

*Optical Disk Players.* We were shown several MUSE disk players designed for prerecorded MUSE material. With the relatively few hours of programming planned by NHK for its satellite, the disk player is a logical low-cost solution to added programming for beta sites like Hi-Vision Cities.

### Available in 2-4 years

*Cameras.* For HDTV to compete successfully with 525 line television in the Japanese consumer market, the capability of S-VHS and HI-8 to take pictures as well as show them must be available in HDTV. Therefore, consumer cameras will be available. The effort to produce these will drive the costs of high-performance lens systems for small formats the way the 35-mm consumer camera boom did for that format.

*Baseband VCRs.* Since the MUSE encoder has little likelihood of becoming portable, a recorder that can take in camera signals will be necessary to complete the system.

*Camcorders.* These will be a logical evolution of the above two items, and may come first, depending on the manufacturers' focus.

*Flat Screen Receivers.* Considerable money and effort is being invested in flat screen technology in Japan. This is understandable,

since a flat screen capable of HDTV resolution has numerous industrial applications as well as being the perfect companion to the next generation workstation. The time frame here is not clear, but given the commitment, ultimate success is likely.

## **HDTV CONNECTIONS**

HDTV development has, as has been noted earlier, many links to other applications, and as such serves as a driver for the entire electronics industry in Japan. Figure 3.1 shows some of the links, and there are many more. The major effects on electronic device technology will be to drive cost down and data throughput up. HDTV sets will require so much more digital processing than current sets that they will be more like a Cray Supercomputer with a big screen than what we have come to know as a TV. Consumer use patterns will likely not change easily to accept the idea of an entertainment screen that doubles as a computer. However, computers are currently going through a metamorphosis. Today, they largely communicate back to their users in letters and numbers with the occasional still graphic thrown in. Only the fastest workstations and supercomputers are able to create fully-rendered moving images. And even then, the computing is usually done ahead of time, and a short moving sequence is stored on a very large fast disk. The manufacturers of HDTV sets will have in hand the basic technological tools to produce a computer that will be able to generate fully-rendered high-resolution moving images in realtime. Such a generation of computers will make today's workstations as archaic as these workstations make the slide rule.

Applications range from video games that let Johnny fly his X-wing fighter at high speed through a fully-rendered and essentially infinite three-dimensional fractal universe, to pocket-sized communicators that will easily translate in realtime any human language to any other, to manufacturing systems that can retool themselves and communicate with their managers in moving pictures and human language.

Such notions may seem like fantasy today, but these and hundreds more not even imagined today will be real in a few short years. The key issues are cost, throughput, displays, and programming. The aggressive development of HDTV will put Japan in a leadership position in three of these areas. To assume that we in the U.S. will just naturally maintain our lead in programming when the machine to be programmed spent its infancy learning Kanji is optimistic.

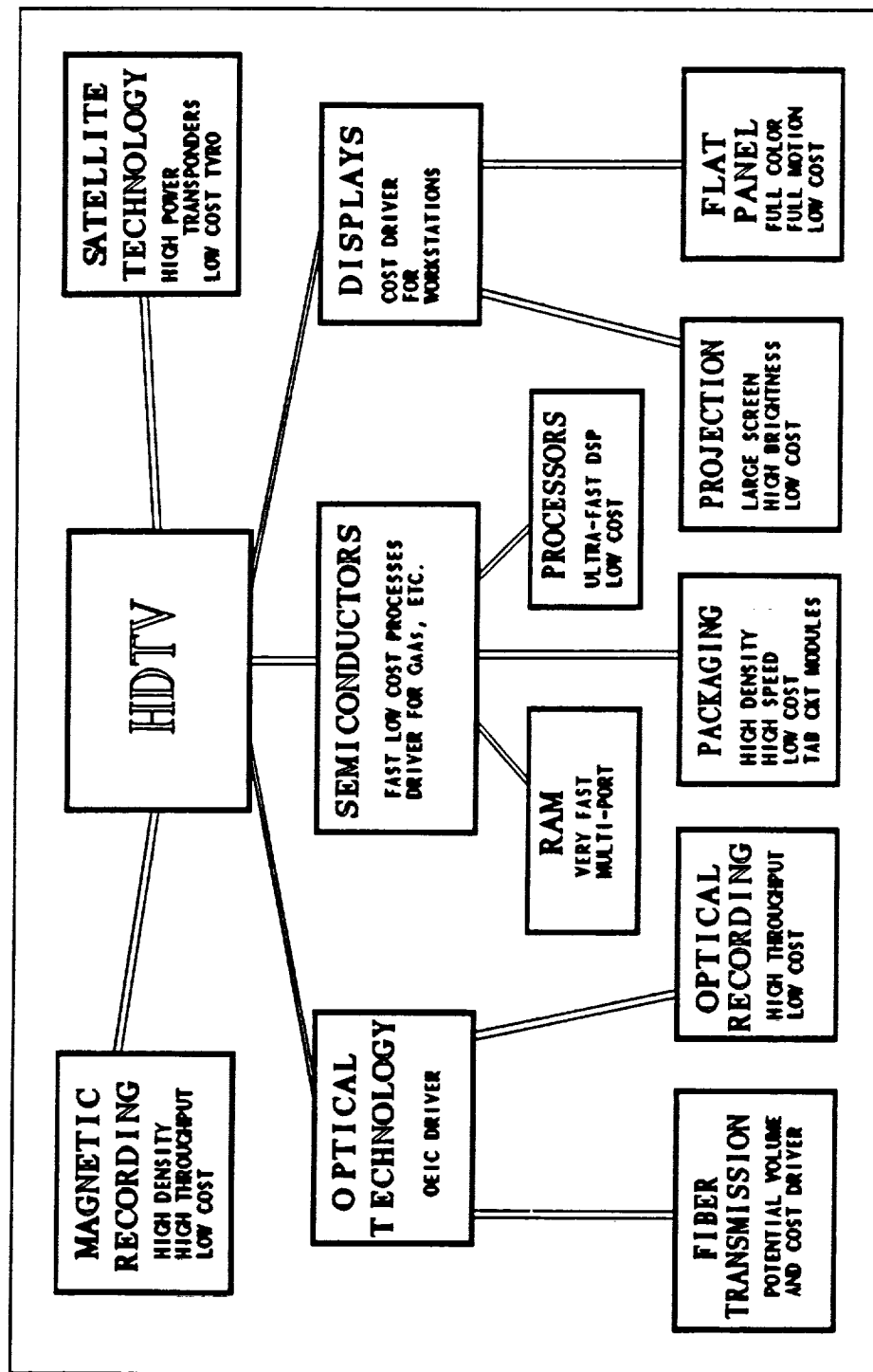


Figure 3.1 HDTV Technology Connections

## REFERENCES

1. Intel Corp recently purchased the rights to DVI (digital video interactive) from David Sarnoff Research Center and acquired most of the development staff from the DVI project. Intel is now developing a DSP chip set that will allow high quality moving pictures to be recorded on a compact disk.
2. The Videocipher division of General Instrument Corporation submitted its "Digicipher" proposal for over-the-air digital HDTV to the FCC on June 8, 1990. This system purports to put 1050-line HDTV and four channels of high quality audio into a 16 Mb/s data stream.
3. *The Big Picture: HDTV & High-Resolution Systems*, Congress of the United States, Office of Technology Assessment, OTA-BP-CIT-64:93 (June 1990).
4. A reverse condition exists if several proprietary approaches dominate a market. The mainframe computer business is a good example of this situation. Japanese companies have had much better success in the standardized personal computer market than in the mainframe market.
5. Birney Dayton, "A Hierarchical Approach to HDTV Production Standards," Society of Motion Picture and Television Engineers 131st Technical Conference, Los Angeles, CA (October 21-25, 1989).
6. Personal communication with several different officers at Sony Corp.
7. NHK and Matsushita demonstrated a 1/2-inch professional digital recorder for broadcast use at NAB 1990 that records composite video at greater than 100 Mb/s.
8. Sony Corp showed a High-8 camcorder at NAB 1990 for low cost electronic news gathering and other similar applications.

the Japanese government, the Japanese Standards Association (JSA), and the Japanese Standards Association for Information Technology (JSA-IT). The JSA is a non-profit organization that promotes the development and use of Japanese standards. The JSA-IT is a subsidiary of the JSA that focuses on information technology standards. The Japanese Standards Association for Information Technology (JSA-IT) is a non-profit organization that promotes the development and use of Japanese standards for information technology. The JSA-IT is a subsidiary of the JSA. The Japanese Standards Association for Information Technology (JSA-IT) is a non-profit organization that promotes the development and use of Japanese standards for information technology. The JSA-IT is a subsidiary of the JSA.

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## **CHAPTER 4**

# **JAPANESE HIGH DEFINITION TELEVISION SYSTEMS**

William F. Schreiber

### **INTRODUCTION**

The existence of high definition television as a standards issue is entirely due to the development of a system and equipment in Japan, and to Japanese efforts to have their system adopted worldwide. It is therefore of interest to see just what has been developed in Japan, and to try to discern, from published papers, statements, and actions, Japanese intentions for the use of their system both in Japan and elsewhere.

### **HISTORY OF THE JAPANESE DEVELOPMENTS**

With typical foresight and willingness to invest money in order to secure markets many years in the future, the Japan Broadcasting Corporation (NHK) began development of HDTV in 1970. The program was orchestrated by NHK, which did the system development and preliminary development of equipment, while the commercial apparatus--cameras, displays, recorders, and ancillary products--were developed by the major domestic electronics corporations, including Hitachi, Mitsubishi, Sony, NEC, Toshiba, and Ikegami. From the first, the plan was to implement HDTV in Japan as an entirely new service, delivered to viewers by direct-broadcast satellites (DBS), and intended to supplement, rather than replace, the existing over-the-air (terrestrial) system, which would continue to employ NTSC, the color standard used in the United States, Japan, and most countries that use the 60-Hz power line frequency.

Scanning standards of 1125 lines, 60 fields/sec, 2:1 interlace, and 5:3 aspect ratio (later changed to 16:9) were chosen with the stated intention of making the picture quality comparable to that of 35-mm motion pictures (Ref. 4.1). These numbers may be contrasted with NTSC's 525 lines, 59.94 fps, 2:1 interlace, and 4:3 aspect ratio; and the 625/50/2:1/4:3 PAL and SECAM systems used in the 50-Hz countries.

Demonstrations outside of Japan with this system, now called the "studio" system, began in 1981. (In this chapter, quotation marks are used around "studio" to emphasize that the system was not intended for this service, and, in the opinion of the author, is not suitable for use as a studio system, particularly as it uses interlaced scanning.) Experiments were carried out to show terrestrial transmission at 38 GHz and analog transmission in optical fiber. Successful FM satellite transmissions were carried out in 1978. Because the system had a base bandwidth about five times that of NTSC, standard satellite transponder channels of 24 or 27 MHz bandwidth were inadequate, so that a special transponder of more than 100 MHz bandwidth was required. (With FM, satellite channels are normally four to five times the base bandwidth.)

Evidently, it was deemed impractical to use such wide transponder channels. Therefore, a transmission system, MUSE, was developed so that a compressed version of the signal could be transmitted in a normal satellite channel. This system was announced in 1984. MUSE has been demonstrated many times by DBS, and was also demonstrated in terrestrial UHF service in Washington, DC, in January 1987, using two adjacent channels, for a total of 12 MHz RF bandwidth. A MUSE DBS system was operating one hour per day in Japan at the end of 1989.

The National Association of Broadcasters (NAB) and the Association of Maximum Service Telecasters (MST) had earlier urged NHK to develop systems that were compatible with (i.e., could be received by) NTSC receivers and that would be suitable for the 6-MHz channel-allocation scheme used in the U.S. Several such systems, called the "MUSE Family," were demonstrated by computer simulation at the NAB convention in April 1988 and in hardware at NAB in April 1989.

System and equipment developments were paralleled by efforts to have the "studio" system adopted as an international standard for program production and international exchange, but this has not yet been accomplished, primarily because of opposition by European interests. Intense controversy exists in both Europe and the U.S. at the present time over this issue.

## THE NHK WIDEBAND "STUDIO" SYSTEM

A definitive description of the original 1125-line system was given by NHK in a detailed technical report issued in 1982 (Ref. 4.2). It was stated that the system parameters were chosen to give a more psychologically satisfying viewing experience in which the viewing angle would be large enough to give some sense of depth (30 degrees) and the resolution high enough so that, at this viewing distance (about three times the picture height or 3H), the image would not be noticeably blurry. A wider screen (5:3 rather than NTSC's 4:3) was felt to be very important for an improved sense of realism (Ref. 4.3).

Actually, as in any system design, the final parameters were the result of compromises between ideal values and affordable values. Widening the screen and increasing the viewing angle as well as the resolution leads to wider video bandwidths. When the bandwidth is increased, camera sensitivity and signal-to-noise ratio (SNR) go down, costs go up, and fewer programs can be accommodated within an overall spectrum allocation.

Generally speaking, the NHK choices were reasonable. There are two questionable decisions, however. One is to use interlace and the other is to use vestigial-sideband transmission (VSB) for AM transmission.<sup>1</sup> The use of interlace is justified only on the basis that HDTV is to be a straight-through system without any storage. As a result, the cameras, channel signal, and display are all synchronous, just as in the NTSC monochrome standard adopted in 1941. Even in 1970, many would have argued that progressive scan would give much better results and would simplify transcoding between various standards. Twenty years later, it appears that all new TV systems will use frame stores, so that the argument for interlace is now even weaker (Ref. 4.4).

Since the "studio" system was originally designed for FM satellite transmission, it is possible that the decision to use VSB for over-the-air AM broadcasting in the system proposal made to the FCC simply did not receive enough attention at the time. At present, it appears to be a simple error. Double-sideband quadrature modulation, as is used for the color information in NTSC, is much more effective. With it, MUSE would require an RF bandwidth of just over 8 MHz, whereas with VSB, there is considerable doubt as to whether the claim that it will fit within 9 MHz is actually justified.

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<sup>1</sup> NHK believes that the 1125/60/2:1 interlace system is practical from the point of view of picture quality and implementation of equipment. Also, VSB-AM is only one of many modulation techniques that could be used.

## THE MUSE COMPRESSION/TRANSMISSION SYSTEM

The "studio" system required a bandwidth of 32.5 MHz--20 for luminance, and 7 and 5.5 for the two chrominance signals.<sup>2</sup> To fit into one normal FM transponder channel therefore requires a bandwidth reduction of about 4:1. MUSE accomplishes this by two methods (Ref. 4.5). Halving the diagonal resolution by means of transmitting only every other signal sample, interleaved line to line so as to give a 45 degree sampling pattern, provides a factor of two. Another factor of two is gained by reducing the frame rate to 15 fps by sending alternate samples on alternate frames (Ref. 4.6).

At the receiver, a clever motion-adaptive interpolation method completely eliminates the sampling structure due to the effective 4:1 interlace and also eliminates much of the blurring of moving objects that would be expected with nonadaptive interpolation. The basic scheme is to interpolate temporally in the stationary image areas and spatially in the moving areas. This technique would reduce the resolution of moving objects by a factor of two. The blurring would be most noticeable when the cameras were panned. The original system used one motion vector for panning, the receiver performing motion-compensated interpolation. MUSE pictures have been getting better and better, however, and it is possible that a more sophisticated motion compensation is now being used.

MUSE pictures look very good. Although there is some loss of sharpness with motion, the reduction in picture quality is much less than might be expected with a 4:1 reduction in the transmission rate of image samples. It may well be that limited camera-tube resolution is masking some of the loss in resolution. The lack of interline flicker due to interlace (interline flicker is often noticeable in NTSC) gives strong evidence for this speculation. If this assumption is true, then the difference between the "studio" system and MUSE will eventually become more evident with the development of better camera tubes. Figure 4.1 shows the resolution of both the "studio" system and MUSE.<sup>3</sup>

## SYSTEMS SPECIFICALLY DESIGNED FOR U.S. BROADCAST USE

Since the original development work was intended for DBS use, and not to replace NTSC and PAL in terrestrial broadcasting, no attention seems to have been given in Japan to conforming to terrestrial channel widths used in the U.S.

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<sup>2</sup> NHK gives 34 MHz for the "home use" system - 20 for luminance, 7 for the luminance, and 7 for the two chrominance signals.

<sup>3</sup> NHK states "From our experience, the picture quality of MUSE system increases when we use a higher performance HDTV camera."

and Japan. Likewise, the overwhelming preference of U.S. broadcasters for a compatible system seems not to have been made evident to NHK until the specific request of NAB and MST to develop such systems (Ref. 4.7). As a result, the Japanese are not ahead of the world in all aspects of HDTV system design. The compatibility issue is dying away in the U.S. Nevertheless, the Japanese are actually several years behind in one aspect of primary importance, at least in the U.S. Specifically, they appear not to have yet started thinking seriously about systems designed to work well in today's over-the-air channels.<sup>4</sup>

In response to the American request, NHK proposed the so-called MUSE Family, which now includes Narrow MUSE, a 6-MHz version of MUSE that is not compatible with NTSC, plus several compatible systems (Ref. 4.8). These compatible systems are not really MUSE systems at all, as they do not use subsampling. They hide enhancement information in various parts of the NTSC signal and also transmit it in a second channel in one case. Table 4.1 and Figures 4.2 and 4.3 show some aspects of the MUSE Family.

### **Narrow MUSE**

Narrow MUSE is a version of MUSE in which the transmitted signal is 750 lines, 2:1 interlace, 60 fps, with a bandwidth of 6 MHz. The 750-line signal is derived from an 1125 source and reconverted to 1125 lines in the receiver for display. A receiver capable of handling Narrow MUSE and MUSE (now called MUSE-E) would cost little more than the normal MUSE receiver. The main difference in performance between Narrow MUSE and MUSE should be a reduction in diagonal resolution and some loss of vertical resolution. As actually exhibited at the 1989 NAB Convention, the motion compensation did not seem to be as effective, but no doubt this deficiency can be removed.

### **NTSC "MUSE"-6**

All compatible systems, such as this one, which uses a single 6-MHz channel, must accommodate the difference in aspect ratio between NTSC and HDTV. This may well be one of the most difficult problems. Certainly it has been the subject of a great deal of shallow thinking. At the NAB Convention, NHK showed two different methods of accomplishing this. In the "top-and-bottom-mask" or "bar" method, 25% of the theoretical picture height is left empty of picture material on NTSC receivers, so that the remaining image area is 16:9. The 16:9 HDTV receiver screen, of course, is filled. Thus the

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<sup>4</sup> According to NHK, terrestrial transmission of HDTV having equivalent picture quality with MUSE is very difficult when only 6 MHz RF bandwidth is used. SHF terrestrial broadcasting of HDTV using wider RF bandwidth than 6 MHz may be appropriate.

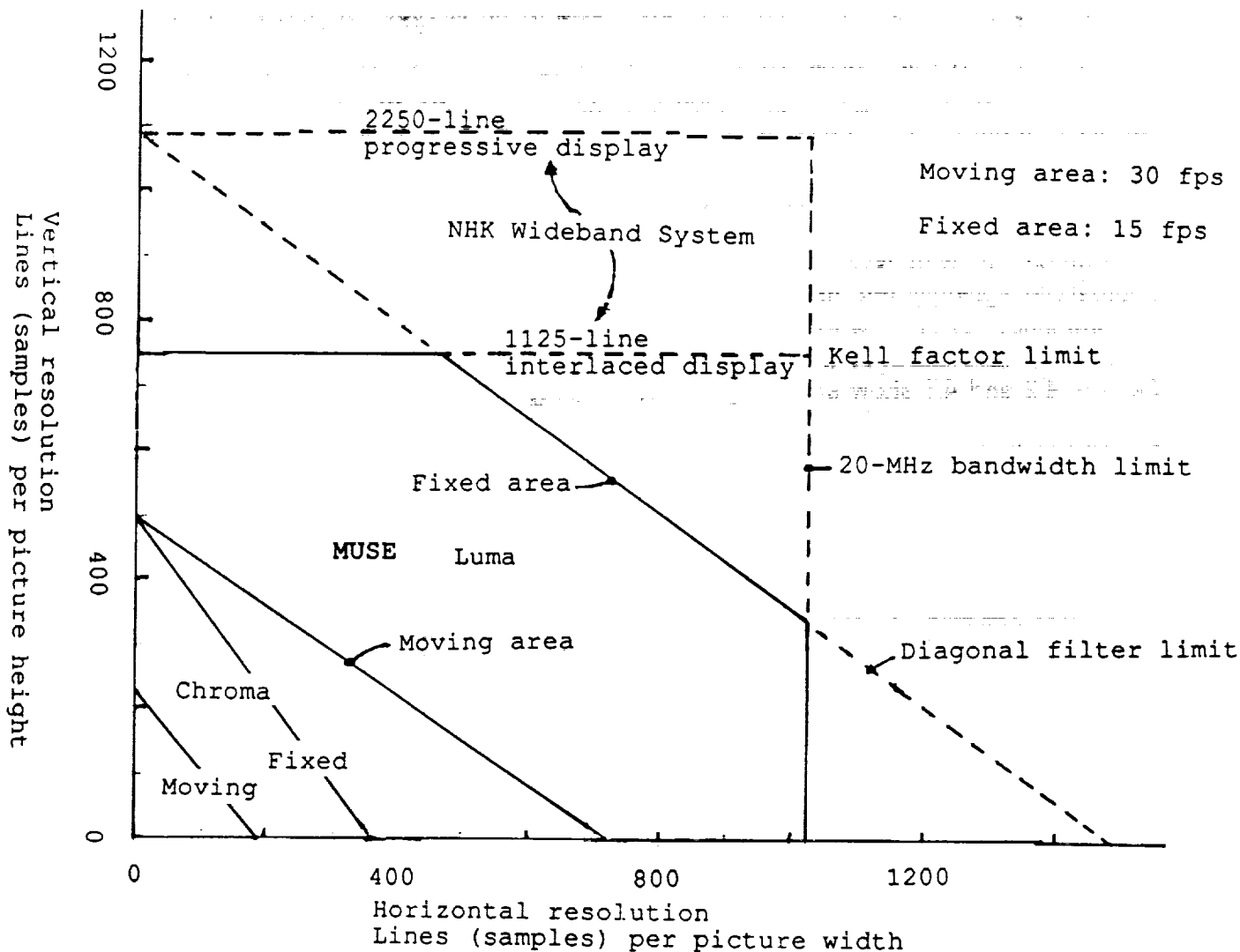


Figure 4.1. Resolution of the NHK Wideband System and MUSE

Both systems have about 1070 active lines, so that resolution on an interlaced display is about 780 lines/picture height. The exact horizontal resolution of the wideband system is governed by camera resolution and bandwidth assigned to each component. At bandwidths of 20, 7, and 5 MHz, this comes out to 1007, 383, and 252 for L, C1, and C2, respectively. The use of a diagonal filter and 4x subsampling for bandwidth compression in MUSE lowers the diagonal resolution as shown. The moving-area horizontal resolution is also halved to give the results indicated in the diagram. The static luminance resolution is further limited by the camera and display, but the other resolutions are set by the system parameters.

Table 4.1

## THE MUSE FAMILY

	System	Bandwidth	Compati- bility	Aspect ratio expansion	Resolution (lines/picture width)	HDTV <sup>*2</sup> ADTV aspect ratio	NTSC <sup>*3</sup> aspect ratio
HDTV	MUSE	9MHz	no <sup>*1</sup>	-	1020	16:9	16:9/4:3
ADTV	NARROW MUSE	6MHz	no <sup>*1</sup>	-	1010	① 16:9	16:9/4:3
	NTSC- MUSE-9	9MHz	yes	top-bottom mask	960	②	16:9
					900	③	
				side picture	900	④	4:3
	NTSC- MUSE-6	6MHz	yes	top-bottom mask	960	⑤	16:9
					680	⑥	
				side picture	900	⑦	4:3

\*1 An experimental low-cost downconverter has already been realized.

\*2 Aspect ratio displayed on HDTV and ADTV receivers.

\*3 Aspect ratio displayed on NTSC receivers.

There are many variants here because of the necessity of conforming aspect ratio. NHK showed two different methods. The "top-bottom mask" method is generally called "letter-box" format in this country. Blank bars are left at top and bottom so that the same image material is shown on the two kinds of receivers. In the "side picture" method, generally called "side-panel" here, the sides of the wide-screen (16:9) HDTV picture are cut off for display on the NTSC (4:3) screen.

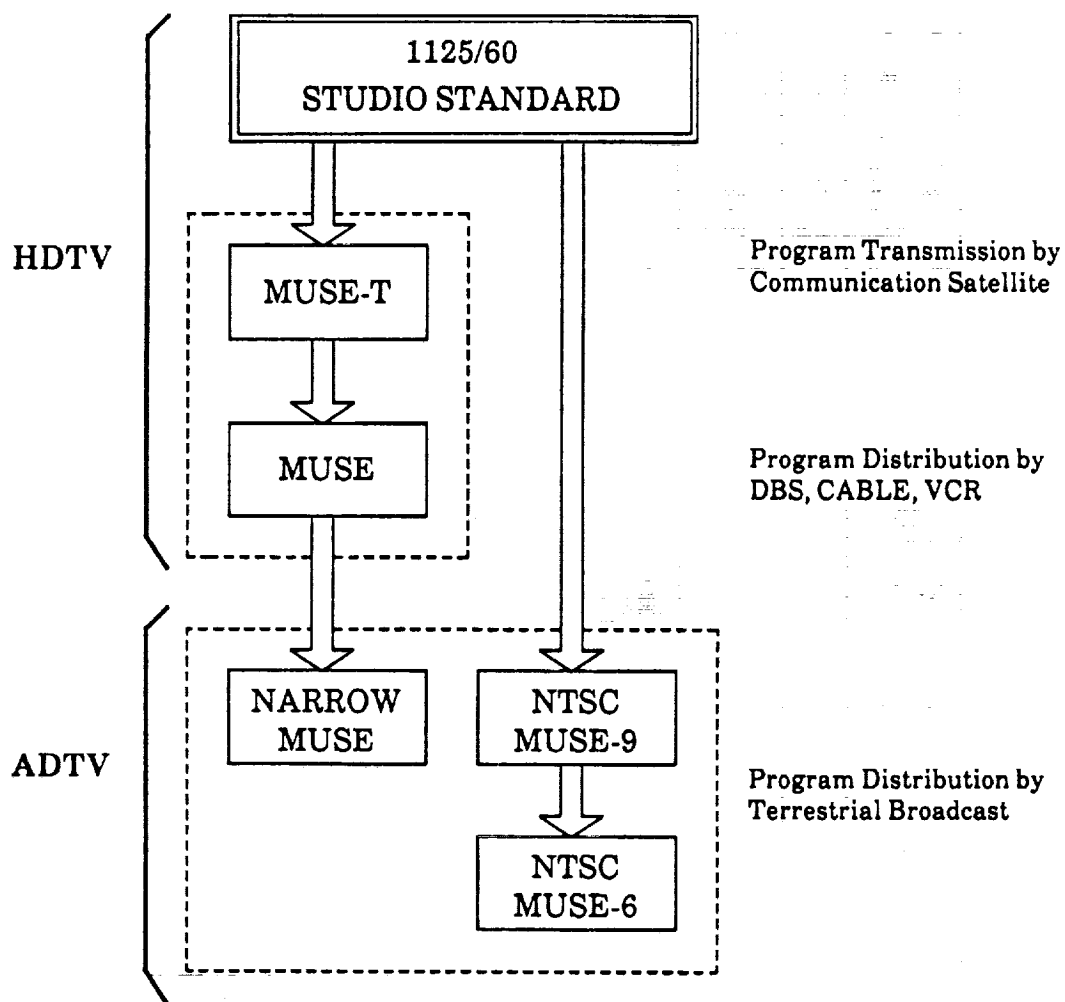
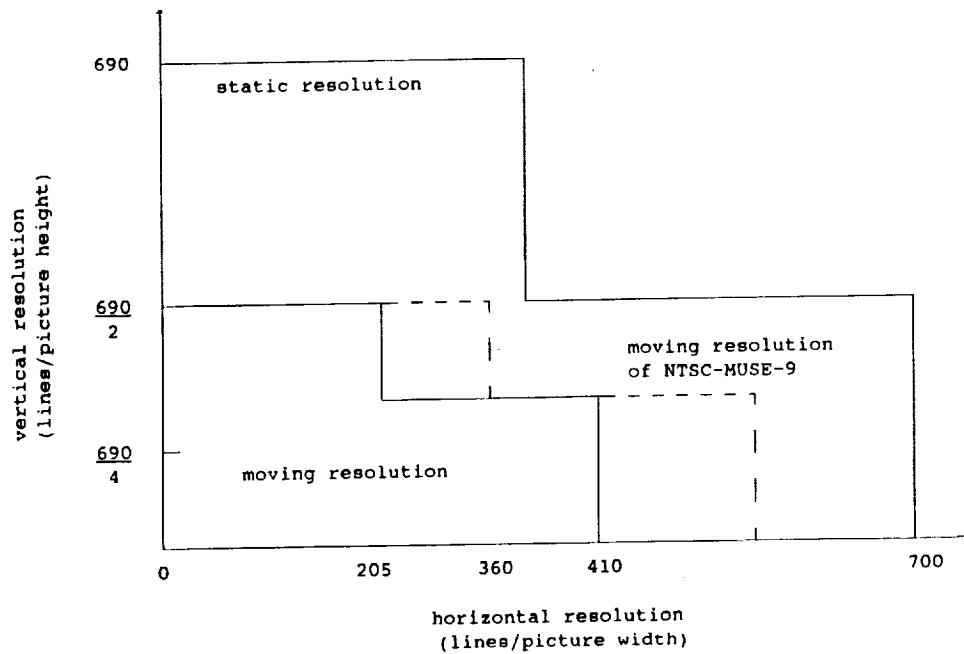
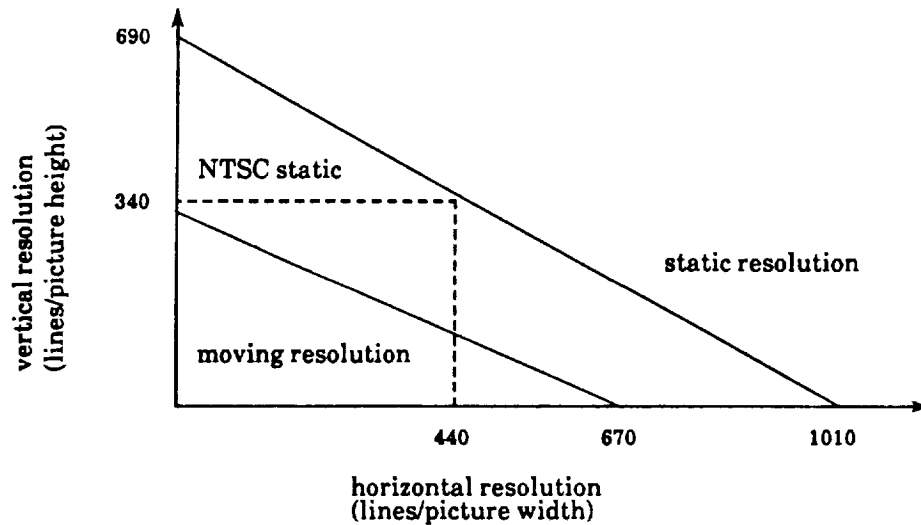


Figure 4.2. The MUSE Family

NHK has proposed a family of systems that fit within the US 6-MHz channel and/or are compatible with NTSC receivers. All these systems are derived from the wideband system by filtering and subsampling. MUSE-T is a higher resolution version of standard MUSE, now sometimes called MUSE-E. Narrow MUSE is a 6-MHz version that achieves its compression by reducing the number of scan lines, and thus, the vertical resolution. It is otherwise quite similar to MUSE and can be processed almost entirely in standard MUSE coders and decoders. The NTSC-compatible systems are not MUSE at all, but utilize a variety of methods to add information to a standard NTSC signal. NTSC MUSE-6 uses a single channel, while NTSC MUSE-9 uses an additional 3-MHz augmentation channel. NHK rates the quality of NTSC MUSE-9 as slightly below Narrow MUSE.



(a) NTSC-MUSE-6



(b) Narrow-MUSE

Figure 4.3. Resolution of the MUSE Family

These NHK figures show its assessment of the moving and static resolution of the MUSE Family. Note that Narrow MUSE is much like MUSE-E except for the lower vertical resolution. The odd shapes of the resolution outlines for the NTSC-compatible systems are due to hiding various pieces of enhancement information in various places in the NTSC signal.

image content and shape shown on the old and new receivers are the same. This is the method proposed for the MIT-RC system and is much like the "letter-box" format used in Europe for wide-screen movies shown on TV. It has the advantage that the bar area at the top and bottom of the screen, otherwise empty, can be used for enhancement information.

NHK's "side-panel" method, like that of the Sarnoff system (ACTV), transmits information for the extra picture area by hiding it within the NTSC signal. The extra area encompassed within the side panels is not seen on the NTSC receiver. It therefore must be devoid of significant picture information, greatly reducing the visual impact of the wider screen. NHK advocates the bar method rather than the side-panel method, partly for this reason and partly because the seams between the side panels and central section are often made visible by channel impairments.

Several other methods are used by NHK to hide information within the NTSC signal, in addition to placing it in the top and bottom bars. Some information is hidden in the vertical and horizontal blanking intervals. For the stationary areas of the picture only, high-frequency enhancement information is transmitted at a lower frame rate by multiplexing it with the upper half of the spectrum of the NTSC luminance and chrominance signals. This is an indirect way of using the "Fukinuki hole" (Ref. 4.9), that portion of 3-dimensional frequency space diametrically opposite to that occupied by the color subcarrier and its harmonics.

### **NTSC "MUSE"-9**

This system is much like the previous one, but in addition uses an auxiliary 3-MHz channel for augmentation information. In the version shown, this extra capacity was used for digital audio and for increasing the vertical and horizontal resolution in moving areas, which are of quite low resolution in the 6-MHz version.

An interesting point is that NHK itself ranks the various systems, in rising order of quality as: NTSC MUSE-6, NTSC MUSE-9, Narrow MUSE, and MUSE-E. Thus Narrow MUSE, with a 6-MHz bandwidth, is better than NTSC MUSE-9, which requires 9 MHz. This shows quite clearly the penalty that is paid for building NTSC compatibility into any new television system.

As exhibited, the 9-MHz compatible system had significantly better resolution than the 6-MHz compatible system. However, both NTSC-compatible systems showed such serious defects in moving areas that it is hard to understand why they were exposed to public view.

## IMPROVED NTSC SYSTEMS

In Japan, under the leadership of the Broadcast Technology Association (BTA), a good deal of effort has been devoted to the development and introduction of improved versions of NTSC. This may partly be due to the fact that NHK's plans call for independent broadcasters to play a rather small role in HDTV, and BTA clearly does not want NTSC broadcasting to be turned into a second-class service.<sup>5</sup>

Improvements are classified into two groups: getting rid of NTSC artifacts and transmission impairments, primarily at the receiver; and raising the resolution and/or the aspect ratio by modifications of the encoder as well as the receiver. Ghost cancellation, which is responsible for much of the image degradation under typical transmission conditions, gets high priority in these efforts. It requires adding a pilot pulse to the transmitter and an adaptive filter to the receiver. All these improvements are to be implemented without substantially degrading the quality of images on today's receivers.

The first stage, called EDTV-1, is already on the market, and the second stage, called EDTV-2, is expected in 3 to 5 years. It remains to be seen how the audience will react to expensive receivers that provide marginally improved reception of programs that are already viewable on existing receivers.

## STANDARDIZATION ACTIVITIES

Since the middle 1970s, the Japanese, aided by some Americans and Canadians, have made a determined effort to get the 1125-line "studio" system adopted as an international standard for program production (studio use) and international exchange. This effort has been carried out in the International Consultative Committee on Radio (CCIR), the Advanced Television Systems Committee (ATSC), the Society of Motion Picture and Television Engineers (SMPTE), and the American National Standards Institute (ANSI). While it is to be expected that Japanese interests should try to use standardization to advance their economic goals (many countries do so), it is more surprising that they have gotten so much help in this country.<sup>6</sup> This is especially remarkable since the NHK system was intended neither for studio nor for exchange purposes. It was intended for a 1970s-type satellite transmission service that did not employ

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<sup>5</sup> According to NHK, several commercial broadcasters are very enthusiastic about HDTV instead of EDTV.

<sup>6</sup> NHK states, "The biggest benefit of the adoption of the single worldwide standard for HDTV is that the unified standard encourages international program exchange. High quality frame number conversion is very difficult even if progressive scanning is used." NHK has encouraged a single standard for broadcasters and users.

modern components such as frame stores or modern signal processing ideas.<sup>7</sup> Interlace makes the 1125/60 signal into one normal satellite transponder channel. In terrestrial transmission service, it is likely to be even more vulnerable to channel impairments than NTSC.<sup>8</sup>

The idea that studio and exchange systems should be standardized before transmission systems are agreed upon is highly questionable from a purely technical point of view.<sup>9</sup> It seems logical that television systems should be designed around the transmission format, by far the most difficult format to devise, since it requires high spectrum efficiency and effective suppression of channel impairments. Since the world is not even close to agreeing on HDTV transmission formats, it would seem that arguing about studio formats, a much simpler technical problem, is somewhat premature.

Transmission systems can only be designed effectively by assuming a certain level of receiver processing power. There is a strong trade-off between spectrum efficiency and receiver complexity. Indeed, if high-quality channel capacity were free, we could use receivers with only minimal processing power. With today's technology, it is possible to put a very large amount of processing power into receivers with only marginal effect on cost, since chips are cheap and displays are expensive. Thus it is now possible to conceive of very sophisticated systems that offer many advantages over NHK's wideband and MUSE systems.<sup>10</sup>

It was easy to get early agreement on the desirability of a single world production and distribution standard. Such agreements-in-principle cost nothing to make. The difficulty in choosing a uniform standard becomes evident only when the costs due to using someone else's standard are calculated. The

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<sup>7</sup> According to NHK, the 1125/60 system has been adopted after due consideration of studio equipment and international program exchange. From the beginning NHK R&D was intended to use digital signal processing and frame memories.

<sup>8</sup> NHK believes that any field number conversion is difficult, not only in the interlace system but also in the progressive scanning system.

<sup>9</sup> According to NHK, transmission and emission of HDTV signals will be on various channels such as terrestrial VHF, UHF, SHF, satellite, cable and fiber. For these channels different coding and modulation scheme will be used. If each transmission or emission system uses its own studio or production standard, then there would be many different systems even in one country. In addition, HDTV will be used also for many industrial fields; so single standard is highly preferable.

<sup>10</sup> NHK believes, it is quite clear that a standard should be set soon to start real service. Technology is always changing. If we wait for technology which may be developed in the future, we can not start any real service. And, if a standard is adopted for the U.S. terrestrial ATV, technologies needed in the system may be obsolete quickly when real service starts.

Europeans probably never had the slightest intention of accepting 1125/60, but centuries of diplomatic experience seems to have taught them never to reject a proposal outright. Instead, they demurred over the quality of transcoding to PAL, which would be universally required for many years to come. When the resourceful NHK engineers solved that problem, Europe finally "just said no" in 1986 and set up the well-funded project Eureka to develop an HDTV system for Europe.<sup>11</sup>

The U.S. State Department, on the other hand, persisted in backing the Japanese system as an international standard for production and exchange until May 1989. By that time, even the ATSC, under a new chairman, had reversed its previous support. Eventually the State Department changed its position, perhaps because of intense pressure from Congress, whose members see HDTV primarily as a trade and competitiveness issue.

While American standardization activities are not the subject of this report, it should be pointed out, in order to put Japanese activities in context, that the Federal Communications Commission (FCC) has decided that the first order of business in the U.S. is to establish an HDTV standard for terrestrial broadcasting. It did this with full knowledge that transmission defects must be overcome and with apparent confidence that the desired quality can be achieved in 6 MHz. Since MUSE cannot meet these requirements, it is largely irrelevant in the U.S.<sup>12</sup>

## JAPANESE INTENTIONS

When the JTEC HDTV panel visited Japan in June 1989, the members were told everywhere that the 1125-line system was developed primarily for the information society of the future. Its application to the next generation of TV broadcasting systems was downplayed. It is true that some of the early Japanese technical papers did mention this distant vision. However, the developments themselves have been directed primarily at an improved system of broadcast television, rather than toward the informational, educational, and transactional services that Americans are most likely to associate with the new world of broadband communications that presumably will arrive with the universal deployment of optical fiber networks. Interactive services are hardly

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<sup>11</sup> The view of NHK is that since EBU is a program user in Europe, it understands the importance of the international program exchange, and at first it was inclined to adopt the 1125/60 system. However, the manufacturers prevented EBU from adopting the system.

<sup>12</sup> According to NHK, the Narrow-MUSE system was proposed to meet the tentative decision by the FCC for the ATV broadcast system with 6 MHz bandwidth for terrestrial broadcast.

ever mentioned in Japanese technical papers, and the MUSE receiver designed by NHK appears to have no special provisions for interconnection to any alternative distribution systems other than DBS and normal terrestrial broadcasting.<sup>13</sup> The Japanese-owned TV companies in the U.S. have disclaimed the proposal for an open-architecture receiver (OAR) (Ref. 4.10), the sine qua non of an information society based on high-resolution systems.<sup>14</sup> The Electronic Industries Association, dominated by foreign-owned TV manufacturers, passionately denounced the OAR concept in a letter to Chairman Patrick of the FCC (Ref. 4.11). The EIA went so far as to say that open architecture, now universally used in personal computers, is dangerous to the user!

NHK and its American supporters continue to champion the NHK system as a production/interchange standard--presently under the guise of "common image format"--with a tenacity inconsistent with an orientation toward a distant vision. It seems much more like an attempt to control the next generation of TV throughout the world on the basis of the work on 1125, much of which is now out of date, and which has been firmly and decisively rejected by the Europeans.<sup>15</sup>

The NHK system is not universally popular even in Japan, especially among the independent broadcasters. These companies, not engaged in the export trade, are primarily interested in protecting their own interests, and they have decided that improving NTSC is much more important (Ref. 4.12).<sup>16</sup>

There is a good deal of talk in Japan of using the "studio" system in other fields, such as education, medicine, printing, and film-making. To the extent that television is now used in industry, education, and the military, a high-definition system that was not much more expensive than NTSC would no doubt prove useful. Computer graphics is already using HDTV. Printing, which is now highly computerized, and in which computer-based page make-up systems are very common, has much more to teach TV than vice versa.

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<sup>13</sup> NHK believes that a MUSE receiver must be designed to receive NTSC and EDTV signals also with high picture quality using digital signal processing and frame memories in the receiver. Some manufacturers have already produced such receivers. A MUSE receiver is also used for a display of the B-ISDN HDTV transmission.

<sup>14</sup> NHK believes that the market will determine whether an open architecture is appropriate for TV receivers.

<sup>15</sup> NHK believes that the standard of the 1125/60 system is a very effective basis for future systems.

<sup>16</sup> According to NHK, many programs are being produced in Japan using the 1125/60 HDTV system by commercial broadcasters as described in a CCIR document (Doc. IWP 11/9-23, 26).

Film-making is a more complicated situation. NTSC does not have high-enough resolution for cinematography, although it is sometimes used for special effects. The 1125-line system does have almost enough resolution, but it still is deficient in dynamic range and camera sensitivity, portability, and power consumption. Although it has been claimed that electronic cinematography is much cheaper than normal methods, this has not been borne out in practice. Much of the supposed savings of HDTV film production is already available in current systems that transfer film to videotape for making editing decisions.<sup>17</sup> The actual production of the film master negative is still done photographically in these systems.

It is worth noting that the Japanese have tried very hard to get the same 1125/60 system intended for DBS to be used for film production. They have so far refused to make a 24-fps progressively scanned system, which would give much better results and would require only minor modifications to equipment.<sup>18</sup> From the technological point of view, this is unexplainable. One can only assume that this is being done primarily to gain additional support for 1125/60, since the film-making market is very small compared to the TV market.

### **THE AMERICAN COMPETITIVENESS ISSUE**

Some American commentators on HDTV view it primarily as an economic issue in these terms: "HDTV is not primarily about beautiful pictures; it is mostly about jobs and money." These sentiments are especially strong in Congress, which is very sensitive to economic issues. From this point of view, the likely dominance of HDTV by the Japanese (and to a lesser extent, the Europeans) is seen as the latest example of the decline of American competitiveness, with near-term trade and federal budget deficits, and with a long-term threat to the American standard of living. Some groups, such as the American Electronics Association, have pointed out both the threat and the opportunity presented by HDTV. If we do not participate, we risk damage to the computer and semiconductor industries; and if we do, we may use this experience to begin to turn around the erosion of American technological leadership.

It does appear to be true, as clearly expressed in a recent MIT report on the decline of U.S. manufacturing, that a combination of circumstances has led

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<sup>17</sup> According to NHK, the HDTV system is used not only for editing decisions, but the editing itself. There are already some movies taken, edited and produced using HDTV systems.

<sup>18</sup> NHK states that any special system with 24 frames seems to be used only for film. From the point of view of economy of equipment and multi-usage of programs, it is highly desirable to use a standard both for film and television.

many American companies to take a very short-term view of what constitutes business success (Ref. 4.13). (Some go so far as to see this as endemic to the whole country, affecting our national willingness to make adequate investments in infrastructure and education.) This has resulted in insufficient funding of the development of new products and processes. Naturally, our ability to compete in the long run absolutely requires adequate investment in the future. When we give up products and markets to foreign companies more willing than we are to forego some of today's profits for the sake of future strength, we put at risk all related products and markets, and we gravely erode our future prosperity.

Coupled with our willingness to see our own shortcomings, there is a common perception that some of Japan's industrial success is due to playing by a different set of rules. For example, many American observers believe that it was widespread dumping, unopposed by the U.S. government, that drove most American TV receiver manufacturers out of business. Japanese attempts to get their HDTV system adopted in the United States, even though it was developed for an entirely different application and is unsuitable for the American TV broadcasting environment, seem like more of the same to many U.S. observers.

In view of the technological situation as well as political and economic factors, there is substantial support for doing something so that HDTV does not repeat recent history in related technologies. However, there is little agreement on what that something should be. There is objection in many quarters to the promulgation by government of an "industrial policy," even though the totality of government action clearly has a major impact on management decisions. Some objections to government action are based simply on a reluctance in Washington to spend money in view of budget problems. However, there are many low-cost steps that might be taken in policy and regulation that would be helpful to American efforts in the field. This does require agreement that it is appropriate for the government to get involved. It is possible that innovative proposals that do not involve large government expenditures may be acceptable.

In the absence of government action, improvement in the performance of U.S. industry must come primarily from within industry itself. Many commentators believe that, government action aside, some self-reform is both long overdue and possible. The most serious complaint about American business management is its excessively short time horizon. Obviously, if a technology takes ten years to produce profits, one must be willing to forego return on investment for that period, or else give up any hope of competing in the relevant markets in the long term. Increasingly, however, product-line managers are given bottom-line responsibility but are expected to pay for long-term research from their own budgets. This kind of business practice is a recipe for long-term failure. A manager, particularly if he feels he may have

moved on before research expenditures bear fruit, has little incentive to act in the long-term interests of the company.

A related attitude, often heard from management/consultants and turn-around artists, is the philosophy of "dogs, stars, and cash cows." The idea is that it is very hard to make a profit in some industries and product lines (consumer electronics is a good example of a dog), while other fields are much more profitable (medical electronics is a star). Some product lines ("cash cows") are relatively mature and make acceptable profits without much continuing development or even attention. The plan then, is to dump the "dogs," go for the "stars," and stay with the "cash cows" as long as they continue to pay off, dropping them as soon as profits begin to falter.

What this philosophy ignores, in addition to the long-term health of the enterprise, is the interrelatedness of markets and technologies. Consumer electronics is a good case in point. Technologically, this field is driving the entire electronics industry, which is well on its way to becoming the largest of all industries. One cannot be selective about the various aspects of electronics. It is impossible to remain an important player in any aspect of electronics without being in all of it, and particularly in consumer electronics. It is extremely difficult to remain an important player without being in the chip business as well. All electronic products are converging to a similar technology, and all electronic markets are similarly related.

## CONCLUSIONS

There is much to admire in the Japanese approach to HDTV. They are particularly to be commended for their long-term views of industrial development and their legendary expertise in low-cost, high-quality manufacturing. If there is any one Japanese practice we should copy, their long-term view is the most important. They have also developed some excellent HDTV components, such as cameras, displays, recorders, and production equipment. However, the system design is suitable only for the original application, which is DBS.<sup>19</sup> Even there, the failure to use frame stores and the consequent employment of interlace are serious drawbacks. The sophisticated MUSE-E system gives very good pictures in a single normal transponder channel. However, it is far from optimum for cable or terrestrial broadcasting, which are of primary importance in the U.S. To the extent that it relies on interlaced signals produced by the "studio" system, it will never reach its best performance.

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<sup>19</sup> According to NHK, the development of the 1125/60 system was not intended only for DBS.

In spite of much recent talk in Japan about the "information society," the 1125/60 system is ill-adapted to serve for any purpose at all if the broadband networks that will form the basis of that society are actually created in the U.S. and Europe.<sup>20</sup> The United States should learn from the Japanese experience in HDTV development, both successful and unsuccessful, and, in devising our own system, come up with something more suitable to our own needs.

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<sup>20</sup> NHK believes that the 1125/60 system can be adapted to any purpose. The 1125/60 system is used for the picture information system using ATM B-ISDN, which is now under development by NTT and other common carriers in Japan. Many kinds of applications of the 1125/60 HDTV system have been reported in CCIR documents. (CCIR Doc. IWP 11/9-008-027)

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1. This is not a very well defined quality, since movie quality is highly variable and steadily improving. It should be noted that 35-mm amateur slides have more than twice the area of a frame of movie film. The 1125-line system, as so far demonstrated, does not have nearly the resolution of amateur slides.
2. T. Fujio et al., "High-Definition Television," NHK Technical Monograph 32 (June 1982).
3. When widescreen movies were introduced in the 1950s, 2.35:1 was the favored aspect ratio, not only to enhance the viewing experience, but also to be as different from television as possible. At the present time, 1.85:1 is the most common film aspect ratio, partly because aspect ratios much wider make cropping for 4:3 television much more damaging to the artistic effect. Note that actual practice varies a great deal. Typical TV viewing angles are much smaller than typical movie viewing angles.
4. Some workers do believe that a progressive-scan HDTV camera is beyond the state of the art at present, but many others would disagree.
5. Y. Ninomiya et al. "A Single-Channel HDTV Broadcast System - the MUSE," NHK Lab. Note 304:1-12 (September 1984).
6. MUSE receivers must use frame stores to derive a 30-frame, 60-field display from the transmitted 15-frame 60-field signal. This removes the principal obstacle to using progressive scan in the studio system, making the use of interlace even more questionable.
7. In my opinion, the insistence on receiver compatibility by American and European broadcasters, although conforming to their perceived short-term interests, is probably not in their long-term interests. Compatible systems cannot possibly provide the high channel efficiency or resistance to analog channel impairments that are now possible in completely new systems, since the deficiencies of NTSC and PAL in this regard are inherent in their design. If broadcast TV cannot compete in picture quality provided by alternative media, then as these media become able to provide programming of equal attractiveness to that provided by over-the-air broadcasters, the latter will lose audience share and eventually go out of business.
8. T. Nishizawa et al., "HDTV and ADTV Transmission Systems: MUSE and its Family," NAB, Las Vegas, April 11, 1988.

9. T. Fukinuki and H. Hirano, "Extended Definition TV Fully Compatible with Existing Standards," IEEE Trans. on Communications 32, 8:948-953 (August 1984).
10. W. F. Schreiber, "The Open-Architecture Television Receiver," ATRP Technical Report 88R (MIT, 12 June 1988).
11. EIA Letter to Chairman Patrick, August 2, 1988. Of record in FCC MM Docket 87-286.
12. An interesting sidelight on the lack of unanimity in Japan is that the BTA originally submitted its EDTV system to the FCC as a proposed American standard. In this role, it would have competed with the proposals of Faroudja and the Sarnoff Laboratory, as well as the compatible proposals of NHK. The BTA proposal has now been withdrawn, apparently because of pressure from NHK.
13. M. L. Dertouzos et al., Made in America Cambridge:MIT Press, 1989).

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## **CHAPTER 5**

# **AN ECONOMIC EVALUATION OF JAPAN'S PUBLIC POLICY INITIATIVES IN SUPPORT OF HIGH DEFINITION SYSTEMS**

Robert B. Cohen

### **INTRODUCTION**

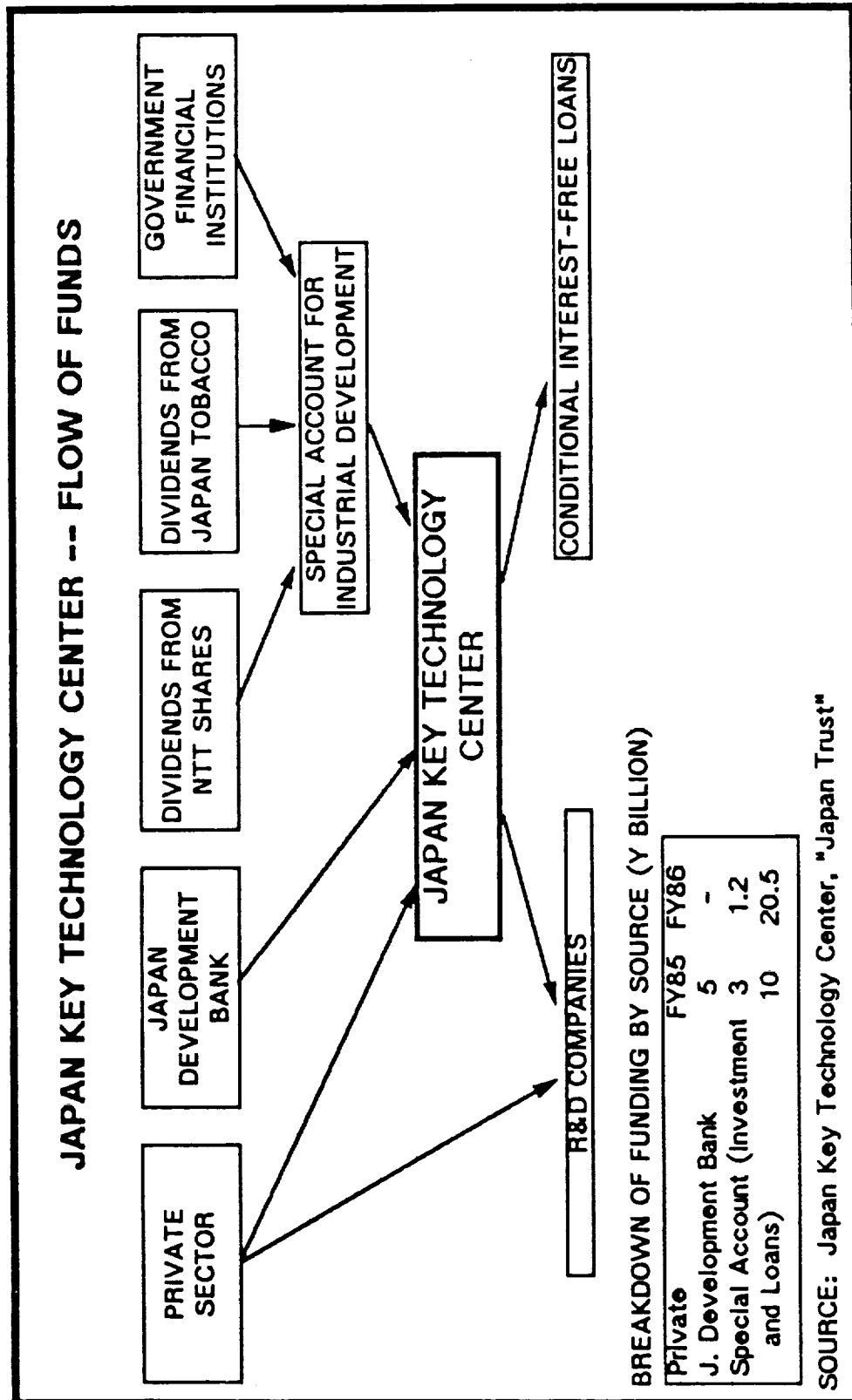
Japan has established an elaborate system of initiatives to support the development of consumer high definition television (HDTV) or what the Japanese call Hi-Vision and high definition systems (HDS), which include high definition imaging systems that are used in computer-aided design and manufacturing, printing and publishing, and the medical, educational, and entertainment industries.

Several features of Japanese policies should be underscored for the readers of this study. First, Japanese government programs are promoting much more than just HDTV. The industrial applications of this technology--what I have called high definition imaging systems, or HDS--receive greater attention than basic research into HDTV. The significant emphasis that has been placed on HDS in Japanese government policies is often overlooked. However, these industrial applications are likely to have a crucial role in shaping the future development of Japan's electronics industry, particularly the next generation of computer and communications systems. Second, Japanese government programs are leading the efforts to develop the infrastructure needed to deploy HDTV technology later in the decade. Without them, Japan's private sector would find it virtually impossible to achieve a meaningful level of commercial

success with HDTV-related products in the 1990s. Third, the more interesting Japanese HDTV initiatives are being administered by a new entity, the Key (or Basic) Technology Research Promotion Center, otherwise known as the Key Technology Center or KTC. This is a public corporation that establishes consortia administered by representatives of some of the leading technology firms and that addresses significant technology development issues such as that of large flat panel displays. But the Center, unlike Japan's ministries, receives its funding from "off-budget" sources, such as dividends on Nippon Telegraph and Telephone (NTT) and Japan Tobacco stock (See Figure 5.1).

Japan's government agencies and the Japan Broadcasting Corporation, *Nippon Hoso Kyokai* (NHK), are playing a leading role in the development and commercialization of HDS and HDTV. According to executives at NHK, work on HDTV began in 1964 and "NHK has spent approximately 20 billion yen [\$148 million at 135 yen to the dollar] for the research and development of HDTV from the fiscal year of 1964 to 1989" (Ref. 5.1). This commitment to HDTV increased substantially in recent years; according to NHK, "... for the fiscal year of 1989, the R&D budget is approximately 3.6 billion yen [\$27 million]" and the HDTV programming budget is "...approximately 3.4 billion yen [\$25.2 million]" (Ref. 5.2). During the years since 1964, at least \$600 million have been spent by the Japanese government and industry to develop HDS and HDTV. Between 1985--when government programs to stimulate HDTV development for commercial and industrial use were first begun--and 1997, a wide range of Japanese government programs will provide \$1.7 billion for HDTV and HDS, according to discussions the JTEC group had with government and broadcasting representatives and statistics published by the main government agencies involved in stimulating HDTV development. These funds include loans from entities such as the Japan Development Bank (JDB), investments in consortia by the Key Technology Center, and grants (see Table 5.3). A substantial part of these funds will be coming from the following sources: the Ministry of International Trade and Industry (MITI), the Ministry of Posts and Telecommunications (MPT), the Key Technology Center (jointly administered by MITI and MPT), JDB, and NHK.

While the sequencing of the state and private sector roles in promoting the growth of HDTV appears confusing to the outside observer, it should be clear that NHK has played a pioneering role in the development of a wide range of technologies and that most government agencies that were earlier concerned with R&D have now shifted their efforts to focus on support for the commercial success of HDTV. NHK has continued to act as the coordinator of much of this R&D, most recently acting as the coordinator of research for the decoding chipsets that were needed to make it possible for cheaper satellite receivers to be provided in more advanced TV sets. Thus, contrary to some impressions that NHK has stepped back from its leadership of HDTV technology



Source: Thomas R. Howell et al., *The Microelectronics Race* (Boulder: Westview Press, 1988):114

Figure 8.1. Japan Key Technology Center--Flow of Funds.

development, it appears to retain a key role in technology development, even as more commercial firms are getting involved in the production of HDTV monitors, HDTV VCRs, and other related equipment.

Commercial firms in Japan have certainly built upon the two decades of research from NHK Laboratories. In addition, they are utilizing the results of a series of more recent research findings on flat panel displays and other projects from MITI and the Key Technology Center. The commercialization of this research is likely to accelerate as the decade progresses. On the other hand, many of the government programs have focused on developing the infrastructure needed to assure the commercial success of HDTV later in the decade. For the most part, this has changed the emphasis in government efforts, moving them from R&D to a direct involvement with assuring the commercial success of products that are most likely to have a major market share only during the last years of this century. Consequently, recent government programs have concentrated upon the satellite broadcasting system for HDTV, more advanced research for better screens for advanced TVs, research on the merging of computers with television, and promoting the early-stage demand for Hi-Vision applications through such projects as the model cities and communities programs and the new media communities and Teletopia projects. Where a government role in research remains, as at MITI, it is to undertake very advanced research projects and not the more practical development work that is more likely to be done by commercial firms. On the other hand, MPT's role is almost exclusively focused on developing the infrastructure and commercial demand needed to spur the success of HDTV in the consumer marketplace later in the 1990s.

While both MITI and MPT are important players in the promotion of HDTV, the rivalry which exists between them should be emphasized. This rivalry has been intense and has resulted in a duplication of efforts by both MITI and MPT in several areas. Each has a regional model program that will select several cities to be designated as special centers for the development of HDTV programming and demonstration locations for public viewing. Each has established a council to promote HDTV. Each has a new media communities (or "Teletopia") program. Many disputes have already arisen because each agency has sought funding for exactly the same concepts that the other has tried to develop. This has led the Ministry of Finance to delay funding for certain programs until it is clear that they will not duplicate the aims of others. The rivalry has resulted in more discord over the direction of government programs and at times makes it difficult to discern the real direction of government efforts to support the commercial success of HDTV.

Another dimension that should be clarified before the policies to promote HDTV are discussed in greater depth is the role of a number of public corporations

which are permitted to undertake special functions in the economy. The Key Technology Center mentioned above is one of the best examples of this type of corporation. It can invest in consortia of private firms and play an active role in such consortia, holding stock in entities such as the Giant Electronics Corporation, just as any other private corporation would. However, these public corporations are very different from MITI and MPT, since they do not receive their budget from the government, but rather from "off-budget" sources, and can remain financially independent of many restrictions that would be placed upon them if they were government entities.

The Japanese call the entire range of HDTV and its related technologies Hi-Vision (sometimes translated Hi- or High-Image), a term which is best reflected in the definition of HDS given above. The terms Hi-Vision and HDS reflect the Japanese view that high definition developments are much more than just HDTV. The major Japanese electronics firms have developed applications of HDS in CAD/CAM, electronic publishing, medicine, security systems, image databases, video on-board traffic controls for autos, and for fashion/fabric catalogs. In addition to these near-future uses, technologists in Japan, as part of an extensive evaluation of future technologies, have identified a number of enhancements of HDS/HDTV technology that are likely to be developed but which face major economic barriers in their commercialization--an indication that some government support may be needed for their early development. These applications are described in a recent report by Japan's Science and Technology Agency (Ref. 5.3).

The impression of the JTEC panel after viewing corporate and government efforts during its visit to Japan was that the Japanese government and most of Japan's largest electronics firms have attached extraordinary significance to HDS and HDTV. For Japanese government and corporate leaders, HDS and HDTV represent a significant economic transformation. They are moving the world's industrial structure into an information systems age, characterized by products and systems that integrate voice, data, and video communications. The developing HDS industry is not merely a market for improved television. HDS will create "a series of technologies--for high resolution display, image processing and storage, multi-media services, and the transmission and production of such information---that will find application not only in 'TVs' but [also] across the electronics and computing industries" (Ref. 5.4). Thus, these new technologies need to be understood as part of a move to multi-function, multi-media processing technologies, since imaging or video equipment, computers, and communications equipment will become increasingly interlinked in a single economic market. HDTV is likely to be the central mass-market video product in this transformation.

The economic impact of HDTV products should be considered in light of the integrated information systems of the future. HDTV will serve as the culmination of an evolutionary movement to true digital broadcasting. But in serving as the first form of more advanced television, HDTV provides the means for Japanese firms to strengthen their control over significant economies of scope in the electronics industry. For instance, having an edge in HDTV technologies will open the door for Japanese companies to translate scale advantages into technology advantages, with dramatic improvements in their ability to compete in a number of high technology markets. This would be due to several dimensions in the economies of scope as they concern HDTV. The dimensions include: (1) the interoperable nature of components developed for HDTV, permitting HDTV displays to be used on Japanese computers; (2) technology merging that is facilitated through the use of HDTV technologies in integrated systems that merge the functions of several existing products, such as TV sets and computers; (3) employing HDTV systems as technology platforms for the development of peripheral devices, such as printers, copying machines, cameras, and VTRs; (4) developing the underlying technologies involved in HDTV to advance related technologies such as electronic packaging and new algorithms for digital processing; and (5) using successor technologies to develop broader applications of HDTV such as traffic control monitoring, plant monitoring, automotive on-board navigation systems, and long-distance medical diagnosis (Ref. 5.5).

## **BACKGROUND TO THE HIGH-LEVEL GOVERNMENT COMMITMENT**

### **The Different Approaches Taken by Japanese Government Programs**

Why are government programs an important part of Japan's efforts in HDS and HDTV? From a number of meetings that we attended, it was clear to the JTEC group that if Japan's firms achieve a leading international position in HDS and HDTV, they expect to have a large number of competitive opportunities in new industrial and consumer electronics, computing, and communications products linked to HDTV technology. Indeed, one top executive of the Sony Corporation noted that HDTV "is the most important project to us over many years" (Ref. 5.6). As leaders of several Japanese corporations said to the JTEC group, leadership in HDTV would enable Japanese firms to challenge the dominant position of the leading U.S. computer and communications equipment firms (Ref. 5.7).

By the late 1990s, profits from sales of high definition products are expected to enable Japan's electronics industry to support large scale production of the most sophisticated memory chips and electronics devices that are an integral part of high definition televisions and VCRs, as well as many other types of

electronics equipment. This might pose another significant challenge to the U.S. electronics and semiconductor industries, particularly if U.S. firms are unable to develop a more substantial base in consumer electronics.

Japan's government policies for HDTV recognize the need to reduce the risks faced by Japanese corporations that are pioneers in developing Hi-Vision systems for industrial and commercial use (Ref. 5.8). Since the initial demand for industrial applications is likely to be limited, leasing companies have been established to facilitate the use of Hi-Vision equipment by industrial firms. In addition, programs to assist smaller firms with high definition systems provide instruction in how to use Hi-Vision systems in industrial settings. Some government programs subsidize the development of video programming that is needed for Hi-Vision equipment to be useful in manufacturing settings.

The government programs are well funded and offer some unusual incentives to participating companies. Besides relying on the traditional operating and capital budgets of the government of Japan, government support for HDS/HDTV R&D and programs comes from a special capital budget. This budget supplies funds from dividends from government-held shares of NTT, Japanese tobacco taxes, government financial institutions, the Japan Development Bank (JDB), and other special accounts.

While two major agencies have been especially prominent in promoting HDTV, a new body that has been established jointly by MITI and MPT, the Key Technology Center, is taking on an increasingly important role in this area. While the Key Technology Center has focused primarily on telecommunications and new media efforts that are only indirectly linked to HDTV, its public status has made it an attractive institution for promoting high definition television and imaging, with its reliance on industry-oriented consortia as the vehicle for devising technology advances as the chief advantage. The Key Technology Center's best known efforts since 1986 have been to organize the SORTECH consortium to promote the development of higher-density semiconductors of 16 megabit and above density using Synchrotron orbital radiation, and to establish a series of regional demonstration schemes for advanced communications (Ref. 5.9). But the Key Technology Center's significant role in HDTV has not been so well known.

The Information Network System and Teletopia initiatives that are discussed in greater detail below will construct fiber-optic networks that will provide the infrastructure for a possible future shift to terrestrial HDTV broadcasting and more immediate industrial use of land-based HDS systems. This infrastructure will facilitate greater use of HDS by industry and consumers because broader bandwidth is needed before new terrestrial uses become commonplace. The

availability of broader bandwidth at low cost would be likely to result in a large increase in demand for high definition systems.

The most important programs that have been announced are the following:

The Hi-Vision Cities Program, a \$111 million effort by MPT that will establish public HDTV systems in 18 cities over the next few years. Much of the funding is likely to come from JDB lending to "third sector" entities.

The Hi-Vision Communities Program, a parallel \$111 million effort under the aegis of MITI. This initiative will include 10 to 20 communities in early efforts to bring HDTV to the public; important tax benefits will offer incentives for private companies to participate in the program. Much of the funding is likely to come from JDB lending to "third sector" entities.

An HDTV satellite initiative that plans to launch two HDTV direct broadcast satellites in 1990-91 as part of a 78.4 billion yen (\$581 million) effort by NHK, Japan Satellite Broadcasting, and the National Space Development Agency (NASDA).

An HDTV satellite procurement corporation that will be established by MPT and is to raise 100 billion yen (\$741 million) in capital by 1991-92 to develop and launch a more sophisticated HDTV satellite in 1997.

The Giant Electronics Technology Corporation, sponsored by the Key Technology Center, which will develop the technologies needed for large flat panel displays. Initially proposed by MITI as a massive seven-year, 10 billion yen (\$74 million) effort, this has now been scaled back to 2.8 billion yen (\$20.7 million).

### **The Types of Advanced Television**

In Japan, the upgrading of advanced television will include at least two stages: the move to extended definition television, or EDTV, which is also called "Clear-Vision" by the Japanese, and a later shift to HDTV, which is called "Hi-Vision." EDTV will "improve picture quality by modifying existing (NTSC) system standards" without changing the number of scanning lines (see Table 5.1). Thus, EDTV will be compatible with the present generation of sets that

Table 5.1

## A COMPARISON OF NTSC, EDTV, AND HDTV

Improving definition for tomorrow's television broadcasting			
	1960	1989	
Terrestrial broadcasting VHF, UHF	NTSC color television	<b>EDTV (1st generation)</b> Higher definition through improvements in both transmission and reception (including improved camera systems, progressive scanning receivers and ghost image cancellation)	<b>EDTV (2nd generation)</b> Higher definition, wider screens, higher quality sound and other improvements with respect to the first generation EDTV
Satellite broadcasting	1984 NTSC direct satellite broadcasting	<b>1990 HDTV</b> Vastly improved definition through a new system offering twice as many scanning lines, wider screens and more dynamic sound	

Source: MPT Broadcasting Bureau, *Advanced Television (ATV): The Promise and the Challenge* (Tokyo: Simul International, Inc., 1989):7.

use NTSC system color broadcasting. HDTV, as planned in Japan, will not be compatible with these NTSC sets. In the first generation of EDTV, transmission and reception will be upgraded by using digital controls to overcome ghosts and enhance picture quality. In the second generation of EDTV, the main changes will be: (1) additional memory chips in sets to eliminate flicker and color crossing; and (2) receivers with a format visibly different from today's sets (see Figure 5.2), having the dimensions of a more rectangular movie picture (compared to the squarish format of today's sets and first generation EDTV) and higher fidelity sound reproduction. Ultimately, EDTV images will have about twice as many pixels, or picture elements, as existing NTSC television receivers (Ref. 5.10).

HDTV will be far superior to other systems. The wide HDTV screen, with dimensions similar to the second generation of EDTV, will contain twice as many scanning lines as NTSC systems (1125 vs. 525), "...as well as twice the number of horizontal pixels and a 30 percent wider screen." HDTV will, therefore, have "roughly five times as many pixels as its NTSC counterpart" (Ref. 5.11). This will give HDTV four advantages over other systems: (1) images will be much sharper; (2) viewers will be able to sit twice as close; (3) sound quality will be the same as that in compact disks; and (4) the image will be useful for studio recording, for high-quality printing, and for cinematography. However, special problems had to be overcome to broadcast HDTV in Japan. Since so much additional information had to be transmitted, satellite broadcasting was selected. MUSE/NTSC converters with custom LSIs have already been developed by some manufacturers to make it possible to receive HDTV broadcasts on existing sets. In addition, a compression system had to be designed to divide HDTV signals into four parts so that the volume of transmitted information could be reduced to a more manageable size. This system, called MUSE, or "multiple sub-Nyquist sampling encoding" system permits broadcasting over a single 27-MHz channel from a satellite (Ref. 5.12).

### **Japanese Expectations of a Substantial Market for HDTV**

The sizable potential commercial market for industrial HDS and HDTV has led MITI, MPT, and NHK to play a role in the development of Hi-Vision. The two government entities envision great benefits for the Japanese economy as a result of the new demand that Hi-Vision will create for Japanese electronics products (including semiconductors and displays) and the development of Hi-Vision as a group of products that will almost erase the gap between computing and communications, opening additional market opportunities. For NHK, the nation's leading broadcaster, the motivation to promote the development of Hi-Vision stems from the aim of creating more attractive programs in high definition that will enable it to retain older viewers and attract

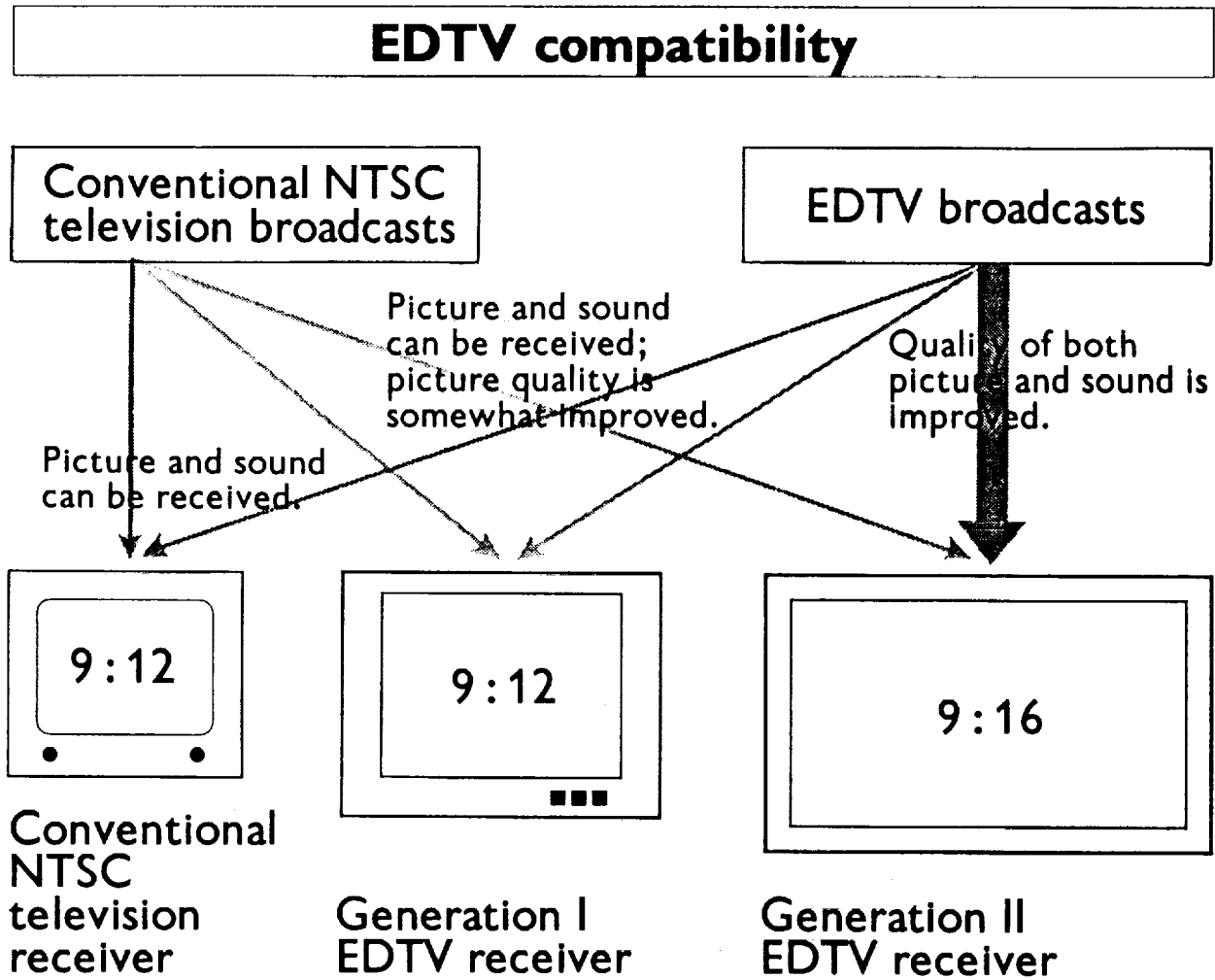


Figure 3.2. Changes in the Characteristics of Television

Source: MPT Broadcasting Bureau, *Advanced Television (ATV): The Promise and the Challenge* (Tokyo: Simul International, Inc., 1989):13.

newer ones, keeping it in the leadership of Japanese TV and maintaining its political support for the monthly fee that it charges users (Ref. 5.13).

Official Japanese figures predict phenomenal growth in sales of HDTVs, as well as in industrial use of high definition systems, and in the development of related software. According to estimates from MPT, the total consumer broadcast market, including sales of HDTVs, is expected to grow from about 250 billion yen in 1990 to 850 billion yen in 1995 and 3.4 trillion yen in 2000 (see Figure 5.3). Figure 5.3 also shows that MPT considers that the production of television sets will account for 97.5 percent of the total spending on HDTV. The information in Figure 5.3 does not provide as broad a picture of the development of the entire high definition systems industry in Japan as is attempted by MITI, which includes industrial sales and more detailed and substantial figures for software production in its own estimates.

Estimates from MITI (see Table 5.2) find the overall demand for industrial and consumer use of HDTV rising from \$7.9 billion in 1995 to \$39.2 billion in 2000. In addition, MITI's figures show industrial sales of Hi-Vision increasing from 132 billion yen (\$9.8 billion at 155 yen to the dollar) in 1995 to 933 billion yen (\$6.91 billion) in 2000. "Software" production and use--the way Japanese agencies describe made-for-TV films, films to be shown in cinemas and possibly rebroadcast on TV, and TV programming--is expected to grow from 218 billion yen (\$1.61 billion) in 1995 to 1.326 trillion yen (\$9.82 billion) in 2000. By 2000, MITI expects industrial use will account for 17.6 percent of HDS sales, and software production and use will account for 25.1 percent of HDS sales. The MPT projections in Table 5.2 indicate that about \$24.7 billion in broadcasting sales will be attained in 2000, somewhat more than the MITI total of \$22.4 billion (for consumer use). However, the MPT figures don't envisage a great rise in software production that is depicted in the MITI numbers. However, the MPT figures do exclude much of the hardware estimates incorporated into the MITI figures, since MPT is less concerned about HDTV sets and other products than it is with broadcasting. MPT figures do not indicate that movie production and video packages will grow rapidly, as can be ascertained by an examination of Figure 5.3.

## **JAPANESE GOVERNMENT PROGRAMS IN SUPPORT OF HDTV**

### **The Size of Funding for HDTV Projects**

Between 1985 and 1995, nearly 240 billion yen (\$1.7 billion) will be spent on programs directly related to the development of HDTV (see Table 5.3). This effort will provide strong support for the commercial introduction of HDTV,

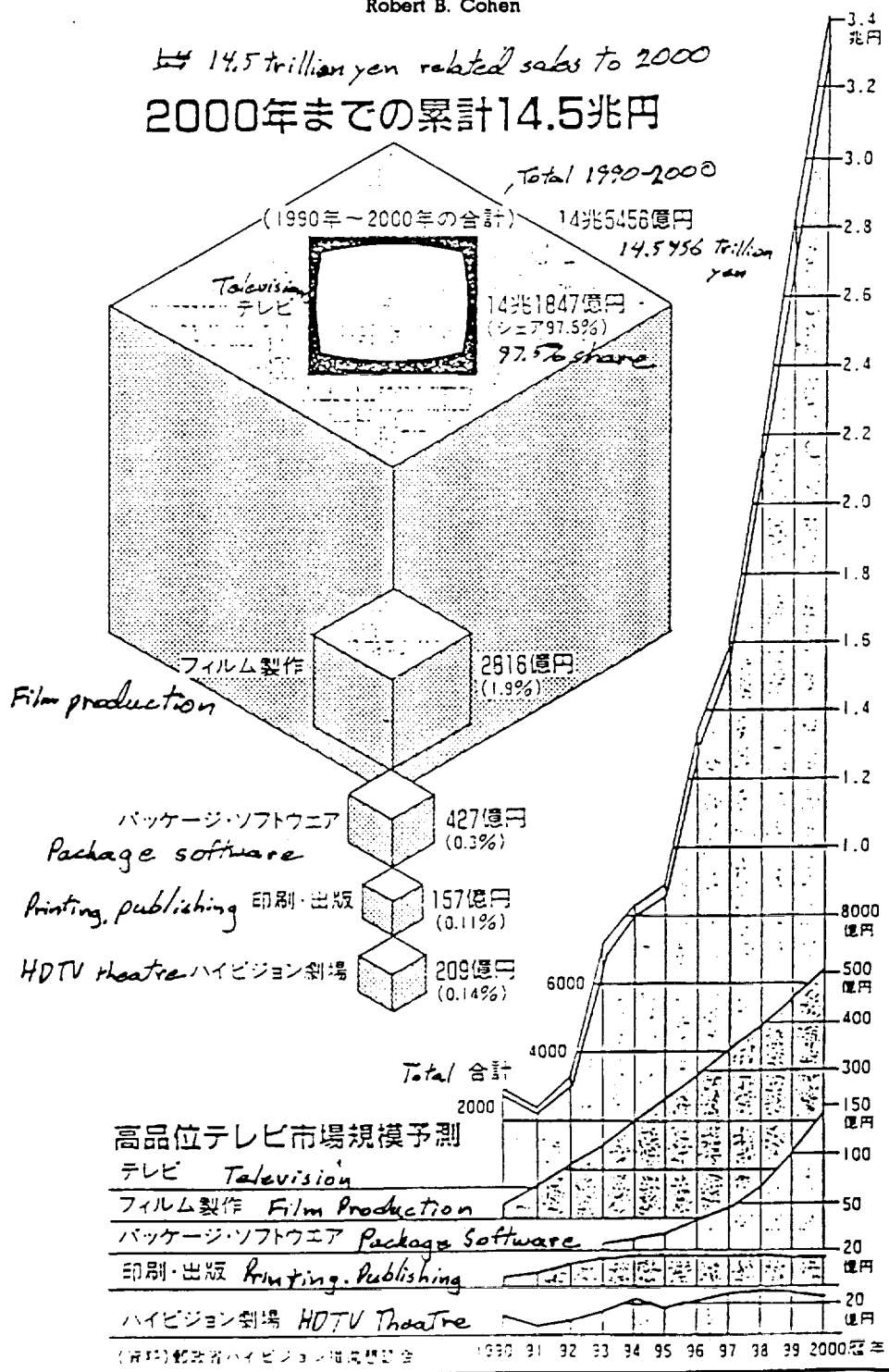


Figure 8.3. MPT's Forecast for the Growth of HDTV

Source: MPT, HDTV Promotion Committee, provided to NSF JTEC members during meeting with MPT Staff in Tokyo, June 2, 1989.

Table 5.2

## MITI AND MPT HDTV MARKET FORECASTS

MITI FORECAST	BILLION YEN		BILLION DOLLARS*	
Image Device Manufacturing	1995	2000	1995	2000
Consumer Use	715	3030	5.30	22.44
Industrial Use	132	933	.98	6.91
Image Software Production	39	427	.29	3.16
Image Software Use	179	899	1.33	6.66
TOTAL	1065	5289	7.89	39.17
MPT FORECAST	2000 FLOW	2000 STOCK	2000 FLOW	2000 STOCK
Broadcasting	3333.3	14184.7	24.69	105.07
Movie Production	50.5	281.6	.37	2.09
Video Packages	14.2	42.7	.11	.32
Theater	2.4	20.9	.02	.15
Printing and Publishing	1.6	15.7	.01	.12
TOTAL	3402.0	14545.7	25.2	107.75

\*exchange rate 135 yen = \$1.00

SOURCE: Originally published in Mark Eaton, "Japanese High Definition Systems: Research, Development, Deployment," MCC International Liaison Office, Austin, Texas, August 22, 1989.

Table 5.3

**CURRENT JAPANESE PROGRAMS FOR HDTV:  
TOTAL SPENDING FOR 1985-1997  
(in billions of yen)**

	Years for Program	Budget	MITI's Budget Estimates <sup>3</sup>
<b>KEY TECHNOLOGY CENTER INVESTMENT PROGRAMS</b>	1985-1993	8.60	
Giant Technology Corporation			2.8
HDTEC - Advanced Image Technology Research Laboratory			3.4
Graphics Communications Technologies, Ltd.			N/A
<b>KEY TECHNOLOGY CENTER LOAN PROGRAMS</b>	1985-1993	1.21	
<b>MITI PROGRAMS</b>	1989-1992	20.30	
Hi-Vision Promotion Center			0.9
Hi-Vision Communities			0.03
<sup>2</sup> Hi-Vision Communications (leasing)			
<b>MPT PROGRAMS</b>	1989-1995	24.70	
Hi-Vision City Program			0.05
Telecommunications Satellite Corporation of Japan (transponder leasing)			--
<sup>2</sup> Japan Hi-Vision: Lease Hi-Vision Equipment			--
<b>SATELLITE CONSTRUCTION AND LAUNCHING FOR HDTV</b>			
HDTV Satellites	1989-1991	78.40	
HDTV Satellite Corporation	1991-1997	100.00	
<b>TOTAL FOR ALL PROGRAMS</b>		233.21 <sup>1</sup>	

<sup>1</sup>At 135 yen to the dollar, this is equal to \$1.73 billion

<sup>2</sup>According to MITI, these programs are not related to the Government of Japan.

<sup>3</sup>Generally MITI believes that the amounts being invested directly in HDTV is much less than estimated by Dr. Cohen. The last column gives some of their estimates.

Sources: J.G. Parker and E.J. Vardaman, *Japanese Developments in High Definition Television*, TechSearch International, Inc., September 1989 and additional Japanese citations on MPT programs in: *Dempa Shimbum*, July 28, 1989, p. 1; *Nikkei Sangyo*, December 11, 1989, p. 7; and *Nikkan Kogyo*, January 17, 1990, p. 7 and March 8, 1990, p. 9, translated and summarized by TechSearch International.

given that the main R&D needed to create commercial HDTV and related technologies has been completed through work at private corporations and NHK (see Table 5.4). This government involvement with HDTV comes at a time when substantial funds are being used to create a digital communications infrastructure; at least another \$10 billion is being spent annually on an advanced communications network that could support greater industrial and commercial use of HDTV in the future, primarily through funding for the Information Network System and the Teletopia program (see Table 5.10).

These expenditures are likely to make it easier for Japanese corporations to succeed in introducing HDTV. According to several observers of the Japanese industrial scene that were interviewed by members of the JTEC group, many Japanese corporations are hoping that these policies will help them capture a dominant share of the world market in both HDTV and equipment that will use high definition imaging, such as computers and communications equipment (Ref. 5.14).

Japanese government policies have been designed to establish the most favorable environment possible for the rapid commercial introduction of HDTV. If these policies to support advanced R&D and the early commercialization of Hi-Vision are successful, Japanese corporations will, in all likelihood, lead all others in HDTV. Government support is critical because commercial and industrial sales of HDTV are expected to be small from 1990 to 1997 or later.

Efforts by NHK increase the likelihood that HDTV will be a major commercial success for Japanese corporations. NHK has coordinated the work of a consortium of semiconductor manufacturers for the creation of a highly simplified decoder system to demonstrate the feasibility of using MUSE LSIs for HDTV broadcasts (Ref. 5.15). Advanced memory chips and specially designed application-specific integrated circuits (ASICs) are needed to dramatically lower the costs of HDTVs so they can be sold to consumers in large numbers by the mid-1990s, especially to consumers who have opened special bank accounts to save for Hi-Vision sets (Ref. 5.16).

### **MITI's Programs for HDTV**

MITI has had a special interest in high definition systems (HDS) because of their application to a broad range of electronics industries. MITI's interest derives from its previous role as the supporter of new technology innovations in electronics, especially in the development of more sophisticated semiconductor technologies through its creation of the VLSI Project and the Synchrotron Orbital Radiation, or Sortech, Project (Ref. 5.17). MITI also developed semiconductor sets needed for satellite broadcasting in its Electrotechnical Laboratories, laser and optical recording technologies through support from its

Table 5.4

PREVIOUS JAPANESE PROGRAMS FOR HDTV:  
TOTAL SPENDING 1964-1989<sup>1</sup>

NHK HDTV R&D	20 Billion Yen	\$148 Million
Private Corporations	60 Billion Yen	\$444 Million
<sup>2</sup> MITI Visual Control Systems Project 1981-85	15.7 Billion Yen	\$116 Million
	<hr/>	<hr/>
Total	95.7 Billion Yen	\$708 Million

<sup>1</sup>Exchange Rate: U.S. Dollar equals 135 Yen

<sup>2</sup>According to MITI, this project does not include the development of HDTV.

Sources: NHK: Letter to author from NHK, June 14, 1989.

Private Corporations: Mark Eaton, "Japanese High Definition Systems: Research, Development, Deployment," Microelectronics and Computer Corporation, MCC International Liaison Office, Austin, Texas, August 22, 1989. A figure of "more than \$770 million" is given for private corporations' spending on HDTV in Nikkei Electronics, October 3, 1988, p. 114, cited in Parker and Vardaman, *Japanese Developments in High Definition Television*, volume on HDTV Developments by Industry, TechSearch International, Inc., Austin, Texas, September 1989, p. 5. However, this figure, and other higher estimates do not appear to be justified.

MITI: Conversations with MITI Officials in Tokyo, June 2, 1989.

Optoelectronics Project, and will develop new chip packaging technologies through its proposed Electron Devices Project. The MITI Electrotechnical Laboratories has provided MITI with an important link to private businesses through its key position in innovative technology projects. For instance, in the VLSI Project, these laboratories developed designs for the 128K and 256K semiconductors that served as the basis for commercial products developed by Japanese corporations (Ref. 5.18).

MITI's efforts in Hi-Vision build upon an earlier initiative called the Visual Control Systems Project. This was a 15.7 billion yen project that was conducted between 1981 and 1985 to measure image information on a 1000-by-1000 pixel monitor (Ref. 5.19).

In meetings with JTEC panelists, MITI staff members described the effort by MITI to create an artificial demand for HDTV in order to create a "virtuous cycle" (Ref. 5.20). Their plan is to target the final HDTV product, the TV monitor, in the hopes that once the price falls to one or two million yen (\$7,407 to \$14,815 at 135 yen to the dollar), demand from businesses would increase rapidly. The further hope is that once the price can be lowered to 300,000 to 500,000 yen (\$2,222 to \$3,704), demand from consumers will follow. The average price for color TVs in Japan in the summer of 1989 was 300,000 yen. Overall, the strategy that MITI plans to follow in promoting the development of HDS is to stimulate industrial market purchases first and then promote consumer applications (Ref. 5.21).

MITI has taken a role in several facets of the development of Hi-Vision by organizing three initiatives to stimulate industrial utilization of HDTV and to promote technological innovations that improve the chances that commercial HDTV will be within the reach of consumers late in the 1990s. These initiatives, whose budgets are summarized in Table 5.5, include the Hi-Vision Promotion Center, the High Vision Communities program, and the Hi-Vision Communications (leasing) joint venture.

*Hi-Vision Promotion Center (also known as Hi-Vision Center [HVC]).* MITI has been the force behind the establishment of the Hi-Vision Promotion Center. HVC was founded in November 1987 by 11 private companies under MITI's guidance. These companies then asked MITI to help convert HVC to a public corporation, a change that took place in July 1988. In early 1989, HVC had 51 corporate sponsors and a budget of 763 million yen (\$5.65 million) (Ref. 5.24). With a similar budget through 1992, its total budget is projected to be 3.05 billion yen (\$22.6 million).

TABLE 5.5

## MITI PROGRAMS FOR HDTV

	Years for Program	Companies Involved	Total Budget (Yen Billions)
MITI PROGRAMS			
<sup>1</sup> Hi-Vision Promotion Center	1988-92	51	3.05
<sup>2</sup> Hi-Vision Communities (Largely via JDB lending)	1989-92	10-20 cities	15.0
<sup>3</sup> Hi-Vision Communications (leasing)	1989-94	69	2.25 est.
TOTAL MITI PROGRAMS			20.3

At 150 yen to the dollar, this is equal to \$135.3 million

<sup>1</sup>MITI has stated that HVC is funded only by the private sector. The annual budget is about 0.3 billion yen. In addition they give the time frame to be 1988-90.

<sup>2</sup>MITI asserts that the funding of each program is coming from the cities, not from JDB. There has been no funding to the program from JDB. Annual budget is about 15 million yen. They also give the time frame of 1989-90 with 19 cities in 1990.

<sup>3</sup>According to MITI, these programs are not related to the government of Japan.

SOURCE: Interviews with Mr. Akiyama of the Hi-Vision Promotion Center, Tokyo, June 1, 1989, and with Mr. Saeki and Mr. Motoshima of MITI, Tokyo, June 2, 1989; J.G. Parker and E.J. Vardaman, Japanese Developments in High Definition Television, TechSearch International, Inc., September 1989, report on NHK and government policies, pp. 11, 22, 27, and 30; and Dempa, August 6, 1989, p.1, as cited in Parker and Vardaman, report on NHK and government policies. p. 26.

HVC will assist smaller firms that want to get involved in HDS, improve the software needed to use HDS in factory automation, and conduct a survey for MITI to identify the most promising targets for promoting the use of HDS/HDTV. It is also developing the "...guidelines for digital interface, film-to-video conversion" machines that will make it possible to show movies in HDTV broadcasts (Ref. 5.25). An area that will draw much of the expertise of HVC is the promotion of what the Japanese refer to as "software," or program development.

HVC's initial efforts were limited, focused only on non-profit efforts. It started in 1988 by helping to fund six small projects, with the Center providing 17 million yen and private companies contributing 500 million yen (Ref. 5.26). In FY 1988, HVC had an annual budget of 700 million yen, or about 5 million dollars. According to its director, it may play a greater role in financing HDS-related projects once the priorities are set between parallel government initiatives, and once the roles of MITI and MPT are more clearly defined. The HVC is likely to provide funds for several of the new "third-sector corporations," entities that are joint ventures of private corporations and prefectures, cities, or other public entities, which are to promote the early use of Hi-Vision. It is expected that many of these joint ventures will have loan funds available to finance up to 40 percent of each project, with the Japan Development Bank acting as one source of the loans. In the summer of 1989, the center was conducting a survey for MITI to determine where funds should be spent to help smaller scale firms to get into HDS. The head of the center said that in the next phase of the initiative, it might be possible for firms such as construction companies to get funds from MITI in order to construct HDTV-related facilities (Ref. 5.27).

Two working committees set the direction for the HVC's efforts. The Development Support Committee tracks developments in HDTV equipment, establishes the framework for later specification development by manufacturers of industrial equipment, and provides evaluations of such equipment. This committee also follows trends in Hi-Vision applications and develops forecasts for Hi-Vision uses in museums, medical, cinematic, and computer graphics applications. HVC's Industrial Support Committee offers financial assistance to software development efforts, tests Hi-Vision equipment, and supports the use of Hi-Vision at special events. HVC participated in the design of the Hi-Vision system for Expo '90 and is now supporting the Japan-China Hi-Vision Project's technical cooperation (Ref. 5.28).

MITI, via HVC, is expected to grant funds to the following types of businesses and organizations to develop Hi-Vision applications: Hi-Vision theatre, or movie-theatre-like places to show HDTV movies to the public; museums, where collections of paintings can be shown to viewers, as at the Gifu Museum; medical clinics, hospitals, and environmental health centers; schools and

universities; large hotels; construction companies; cultural centers; sports centers; chambers of commerce; rehabilitation centers; and airports (Ref. 5.29).

*The Hi-Vision Communities Project.* MITI has also been the sponsor of the Hi-Vision Communities Project, which is to promote the growth of small- and medium-sized businesses that are creating products and services for HDS. Ten to twenty cities would serve as examples of how to broaden the use of Hi-Vision in industrial, educational, and recreational uses. In MITI's budget for the program, there are four parts of the program: (1) research on the development of model systems of Hi-Vision use in local areas; (2) promoting the growth of information-oriented cities; (3) financial assistance for small- and medium-sized companies that participate in the Hi-Vision Communities effort; and (4) tax incentives for the construction and management of model city Hi-Vision systems. To participate in the program, local small- and medium-sized businesses would create products and services for HDS, such as HDTV, high definition cable television, Hi-Vision software/TV programming, and information industry applications of Hi-Vision through enhanced graphics and printing capabilities, among others.

Financing is planned to come from the Japan Development Bank, through lending to "third sector" entities; half of the funds will be for hardware development and half for software firms. Funding is expected to be about 4 or 5 billion yen in the first year (about \$29.6 million to \$37.0 million), with the total budget from JDB expected to be 15 billion yen (\$111 million) (Ref. 5.22).

The MITI program was developed after a nearly identical initiative, the Hi-Vision Cities program, was proposed by the Ministry of Posts and Telecommunications (MPT). MITI's 1989 budget proposal requested that funds be allocated to support certain firms: those which would rent Hi-Vision equipment, such as cameras and display screens; those which would produce and collect movies and other "software" material to be shown on HDS; and those which would install equipment in public viewing places and theaters in the Hi-Vision communities (Ref. 5.23).

There are a series of special financing arrangements that have been formulated by MITI to support the Hi-Vision Communities effort. These loan, tax, and support programs (see Fig. 5.4) include very generous loan provisions, such as no-interest loans that are part of the special financing offered by the Japan Development Bank and the Hokkaido Tohoku Development Fund. These loans are offered to "third sector entities," that is, joint ventures by private corporations and public entities that are expected to take the lead in developing HDTV facilities in public areas and theaters. The loans have a grace period of three years and repayment periods of up to 15 years and are made possible by special funds established through the Japanese Ministry of

Finance. In addition, recipients of financial support are also eligible for data and distribution services that are to be provided by HVC.

(1) Loans

i) Special financing and non-interest loans from Japan Development Bank, and Hokkaido Tohoku Development Fund

a. Special Financing

- Eligible applicants: One who is associated with development of Hi-Vision-related products and software; One who is associated with Hi-Vision promotion business
- Object: Hi-Vision related-products
- Financing rate: less than 40%
- Interest: Special interest (3.05% as of April, '89); A fixed rate
- Periods: Grace period of up to 3 years; period of repayment: within 15 years

b. No-interest loans

- Eligible applicants: "3rd sector entity" which undertakes facility construction business
- Objects: Hi-Vision-related products
- Loan ratio: metropolitan area, 25%; others, 50%
- Periods: Grace period of up to 3 years; period of repayment, less than 15 years

ii) Special financing for small and medium-sized businesses

a. Small and Medium-sized Businesses Public Loan Corporation

- Eligible applicants: One who undertakes business in a regional area using Hi-Vision related products
- Purposes eligible for loan: funds for purchasing Hi-Vision-related products; initiation of business, research and development, and a fund for developing new markets
- Limitation: 100 million yen (5,667 thousand)
- Interest: First 3 years: 3.5 %, the 4th year and after 5.35% (as of April, '89)
- Periods: Facility Capital: less than 15 years (deferment of up to 3 years)  
Working Capital: within 10 years (deferment of up to 3 years)

b. Loan for Promoting Frontier Businesses

- Eligible applicants: Small and medium-sized businesses, certified by prefectural office, which contribute regional economics by using Hi-Vision-related products
- Limitation: Minimum, 20 million yen (\$133.3 thousand); more if the prefectural office decides
- Interest: About 4.2%
- Periods: Facility financing: 5-10 years (deferment: 6-18 months)  
Working Capital: 3-5 years (deferment 3-18 months)

(2) Tax

- Expenditure of money on a Hi-Vision Community promotion corporation can be taken as a loss

(3) Support from Hi-Vision Promotion Support Center \*\* (HVC)

- Distribution of reports prepared by HVC and public information periodicals
- Services such as Hi-Vision information database service

\* \$1.00 = 150 yen

\*\* spelling not confirmed

Figure 5.4. Financial Support System, Hi-Vision Communities Concept

Source: MITI Hi-Vision Application Guide, Hi-Vision Community Concept (July 31, 1989):13. Translation: MCC.ILO

The program includes special financing for small- and medium-sized businesses through the Small Business Public Loan Corporation which will offer deferments of three years on loans for working capital and facility financing, with the first three years of interest at the reduced rate of 3.5% (see Fig. 5.4). Frontier businesses, which are certified by prefectural offices as having the potential to have an important impact on regional economies, will be offered interest rates of 4.2% and have repayment deferred up to 18 months.

*The Hi-Vision Communications Corporation.* The Hi-Vision Communications Corporation has been established as a leasing company under the Hi-Vision Communities Program. It will start with a budget of 2.25 billion yen (\$16.7 million) that comes largely from private companies. Mitsubishi Trading and Dentsu are among the 69 corporations that are sponsors of the leasing corporation (Ref. 5.30). The Hi-Vision Communications Corporation will be similar to the government subsidized computer leasing consortium, the Japan Electronic Computer Corporation (JECC), that was established to reduce the costs faced by Japanese corporations that use computers for industrial production (Ref. 5.31).

However, the Hi-Vision Communications Corporation will not only reduce the cost of leasing equipment, but also consult on how to set up HDS for business uses and provide software that may be needed by smaller firms. Thus, it will be able to act as a "bridge," developing software that is needed by a restaurant, for example, or buying software from a software manufacturer and leasing both the software and the related hardware (i.e., displays, VTRs) to companies that want to use it (Ref. 5.32).

### **MPT's Programs for HDTV**

MPT plays a multi-faceted role in Japanese communications that has become more complex as MPT has taken on a role of promoting the commercial success of new communications technologies in the 1980s. From its beginnings as the Ministry of Communications which controlled mail, the telegraph, maritime shipping, and lighthouses, MPT, while no longer key to R&D innovations as it was in the 1970s, has reinforced its position as a very potent political force for several reasons: (1) it operates the special post offices that account for a large share of Liberal Democratic votes; (2) it manages the world's largest financial institution, the Japanese Postal Savings System; and (3) it supervises Nippon Telegraph and Telephone Corporation (NTT), International Telegraph and Telephone (KDD), new entries into broadcasting, and NHK, the Japanese Broadcasting Corporation (Ref. 5.33).

In spite of its role supporting the commercial success of telecommunications innovations, MPT has traditionally played a back-seat role to MITI, which many Japanese regard as an "ultra-first-class bureaucracy, staffed with some of the finest minds and best managerial talent in the country" (Ref. 5.34). While MITI has attained a status that places it in the same class as the highly prestigious Ministry of Finance, MPT has lagged behind, incapable of gaining the status won by MITI for having been instrumental in promoting Japan's postwar growth and staking claim to leadership of Japan's development of "high-technology industries of the future" (Ref. 5.35).

In recent years, however, MPT has gained ground on its rival because it is now the leader "in Japan's telecommunications industry for the advanced information society" (Ref. 5.36). This mandate has provided it with an important technology-related area that can be called its own and which opens the door for activities in many industries through skills that MPT will be able to provide through communications. Its Administrative Vice Minister, Yusai Okuyama, has said that MPT "regards HDTV as an essential part of the infrastructure of the advanced information society. We are promoting a 'Hi-Vision City' concept to ensure its smooth development and implementation" (Ref. 5.37).

Institutionally, this new mandate for MPT was recognized in the creation of a new telecommunications bureau within MPT that is responsible for the "promotion of the telecommunications industry and supervision of NTT, KDD, and new entries into the business" (Ref. 5.38). Three factors are cited by Japan scholar Chalmers Johnson as the reasons for the improvement in MPT's status: (1) the corruption in organizations such as KDD and NTT that appeared to be excessively independent of government controls in the late 1970s; (2) the inability of NTT to play a responsive role in sensitive trade negotiations with the U.S.; and (3) the desire to reduce government indebtedness that resulted from its management of the railway system, the phone system, and other entities by privatizing the Japan National Railways and NTT (Ref. 5.39).

MPT's technology development priorities were reorganized into six categories in 1989: (1) development of Japan's advanced information infrastructure; (2) introduction of more advanced telecommunications services to regional cities, including promotion of the Teletopia Program; (3) promotion of Hi-Vision Cities and the development of the next generation of television and broadcasting services; (4) advancing international communications; (5) "promotion of joint research and development in leading technologies;" and (6) development of satellite communications (Ref. 5.40). MPT has taken the lead in promoting the utilization of satellite transponders by broadcasters, and research to improve HDTV technology (Ref. 5.41). The main programs being supported by MPT are summarized in Table 5.6.

*Hi-Vision Cities Project.* The Ministry of Posts and Telecommunications organized the Hi-Vision Cities initiative in February 1987 to promote acceptance of HDTV in Japan by providing funds for software development. The program designates cities that are eligible to receive government funds (largely from JDB) and tax relief for HDTV projects that they initiate, such as public theaters for showing HDTV (Ref. 5.42). Hi-Vision Cities is MPT's most visible program for HDTV, drawing upon 15 billion yen (\$111 million), mostly in JDB loans to "third sector" entities, to equip 14 cities with HDTV systems; four other cities have been designated as future candidates (Ref. 5.43).

The Hi-Vision Cities program is like the Teletopia Program that MPT supports to promote the development of communications infrastructures in regional cities. Those cities chosen to participate in the program were selected by MPT's Hi-Vision Concept Committee on the basis of how well they fit one of nine model-city concepts (Ref. 5.44). The concepts were established by a local fact-finding survey completed by March 1988 that identified Hi-Vision applications in cities. Of the 21 cities that applied to be model cities, most were interested in using Hi-Vision to redevelop their city centers and promote "city-style" industry, since they were losing jobs to larger cities. Nagoya, one of Japan's largest cities that was selected to be a model city, hoped to begin using "third sector" (i.e., joint public-private) facilities by the end of 1989 to establish a video zoo and medical applications of HDTV (Ref. 5.45).

The Hi-Vision Cities program is an effort to help cities and smaller firms in Japan's medium-sized cities adopt Hi-Vision technology. The initiative includes, but is not limited to, whetting the interest of the general public in HDTV. Its primary aim is to promote the use of high definition systems for "telecommunication, movies, printing, and education" (Ref. 5.46). Hi-Vision will be used for upgrading the communications infrastructure of Japan since it has three major advantages: (1) it provides better visual images than those available from current technology; (2) it provides greater compatibility among different types of communications media, thus facilitating the integration and reorganization of visual information; and (3) it provides high-quality still pictures for the development of image databases (Ref. 5.47).

The planning body for MPT's Hi-Vision Cities program is its Planning Council, which includes a number of prominent figures from the electronics and communications industries, among them the president of Toshiba, the chairman and the former chairman of NHK, the president of NEC, the president of NTT, and the president and former president of Japan Satellite Broadcasting, Inc. The midterm and final reports of the Hi-Vision Cities Planning Council established selection criteria for model cities and were used to make the initial selection of cities in late 1989. The selection process was delayed, because in

Table 5.6

## MPT'S PROGRAMS FOR HDTV

	Years for Program	Companies Involved	Total Budget (Yen Billions)
<sup>2</sup> High Vision City Program (largely through JDB lending to "third- sector" entities)	1989-92	10 cities	15.0
Telecommunications Satellite Corporation of Japan (transponder leasing)	1991-1995		7.5
<sup>3</sup> Japan Hi-Vision: Leasing Hi-Vision Equipment	1989-	40	2.25

## TOTAL OF MPT PROGRAMS

24.7 Billion Yen<sup>1</sup><sup>1</sup>At 150 yen to the dollar, this is equal to \$164.7 million

<sup>2</sup>MITI states a very low figure for the annual budget for this program--about 24 million yen. They also give the time period as 1989-90 with 24 cities involved in 1990.

<sup>3</sup>MITI states that this program is not funded by the Government of Japan

SOURCE: J.G. Parker and E.J. Vardaman, Japanese Developments in High Definition Television, TechSearch International, Inc., September 1989, report on NHK and government programs, pp. 11, 39; additional Japanese citations on MPT programs in: Dempa Shimbun, July 25, 1989, p.1; Nikkei Sangyo, December 11, 1989, p.7; and Nikkan Kogyo, January 17, 1990, p.7, and March 5, 1990, p.9, translated and summarized by TechSearch International; and Microelectronics and Computer Technology Corporation (MCC), Letter to Senator John Glenn from Barry Whalen and Mark Eaton, July 31, 1989.

early 1989, competition between the Hi-Vision Cities program of MPT and the similar Hi-Vision Communities initiative proposed by MITI caused the Ministry of Finance to stall funding for both efforts until the goals of each effort were more fully differentiated (Ref. 5.48).

The final report of the Hi-Vision Cities Planning Council did recommend that for the present, ten cities should be selected as model cities. Since HDTVs and high definition VCRs are so expensive, the council's report emphasized the need for financial and tax incentives to reduce the cost of purchasing this equipment and building the facilities to house them. The report proposes initiatives for hardware leasing and technological development in local communities, as well as initiatives for improvements in software (program material that can be used in Hi-Vision displays) (Ref. 5.49). Support for software distribution systems is to be given top priority (Ref. 5.50).

The Planning Council's emphasis on software development is not surprising, since the Japanese movie and TV program industry has not been very competitive with its international rivals. Improving the quality of this software--movies and sophisticated graphics and TV programs--is viewed as central to the success of the Hi-Vision Cities concept. It is planned that programming developed for HDTV will combine search, storage, and processing functions in a single image library, utilize combinations of media to take advantage of HDTV's capabilities and enhance the benefits of live broadcasting (Ref. 5.51).

Among the other technologies targeted for development by the Hi-Vision Cities Program in order to promote the wider use of HDTV are wide screen displays, outdoor displays, cable transmission, and optical fiber transmission (see Table 5.7). The plan for model Hi-Vision cities includes financial assistance to develop these capabilities at reduced cost. Plans for the selected cities would also be linked to other regional development efforts tied to telecommunications (Ref. 5.52).

MPT will finance the model cities projects through the Japan Development Bank and the Hokkaido Tohoku Development Bank, using direct investments, low-interest and no-interest loans, and tax incentives. Since the liabilities incurred by special funds that were established to finance Hi-Vision Cities were declared exempt from taxation as a result of the 1989 tax revision for telecommunications projects, four more model cities were to be selected by the end of 1989 (Ref. 5.53).

*Japan Hi-Vision, a Leasing Corporation.* Also, MPT established an HDTV equipment leasing company in April 1989, called Japan Hi-Vision with 40 companies. All of the funding for Japan Hi-Vision comes from the private

sector, and the membership includes NHK, private broadcasters, manufacturers, and banks (Ref. 5.54). Japan Hi-Vision's budget is expected to be 2.25 billion yen (\$16.6 million). Its starting capital is 635 million yen (\$4.7 million at 135 yen to the dollar), but its total authorized capital is 2 billion yen (\$14.8 million) (Ref. 5.55). According to reports cited from the Japanese press, the leasing company will start with a slightly higher capital of 1.8 billion yen that comes largely from private companies. Mitsubishi Trading and Dentsu are among the now 68 corporations that are sponsors of the leasing corporation (Ref. 5.56).

The main goal of the Japan Hi-Vision corporation is to stimulate the development of programs for HDTV broadcasts. It will: (1) rent HDTV equipment and facilities to produce programs that can be broadcast; (2) rent the broadcast facilities and equipment for HDTV; (3) rent HDTV broadcast receiving systems; (4) transmit HDTV videos using communications satellites; (5) plan, produce, sell, manage, and rent (or lease) HDTV video programs; (6) act as a broadcasting intermediary by providing communications or broadcast satellite transponders for broadcasts; and (7) offer HDTV broadcasting consulting services (Ref. 5.57).

The closest precedent for Japan Hi-Vision is the Japan Electronic Computing Corporation (JECC), the leasing corporation that was established to assist Japanese corporations in adopting computers (Ref. 5.58). However, while JECC provided a way for companies to reduce the cost of computers through leasing arrangements, the new leasing corporation will be far more involved with consulting on how to set up HDS for business uses and with providing software where it is needed by smaller firms. Thus, it will be able to act as a "bridge," developing software, buying software from a software manufacturer, and leasing hardware (displays, VTRs) to companies (Ref. 5.59).

*Telecommunications Satellite Corporation of Japan (TSCJ).* TSCJ was established to operate the BS-2 satellites for NHK. To facilitate HDTV broadcasting, NHK will lease a BS-3b transponder to broadcasters. This activity will be supported by funding from MPT, which is "to invest 7.5 billion yen over four years from the industrial investment special account" in TSCJ (Ref. 5.60).

The BS-3a broadcast satellite was to be launched in late 1990, and the BS-3b satellite is to be launched in 1991. In February 1990, two BS-2X backup satellites were lost when the launching rocket blew up. This loss may delay Japan's programs in HDTV, but not substantially. The BS-3a and BS-3b satellites are key to the success of the early efforts to stimulate consumer use of HDTV. Without them, success in commercializing HDTV is questionable. In the 1990s, MPT will establish a procurement company for the BS-4 satellite. Through its ownership of satellites and leasing channels to broadcasters, MPT's

Table 5.7

**EXAMPLES OF THE USES OF HI-VISION TECHNOLOGY  
CONSIDERED FOR INCLUSION IN THE HI-VISION CITIES PROGRAM**

<u>Example</u>	<u>Location</u>	<u>Type of HDTV</u>	<u>Years Available</u>	<u>Expected Cost</u>
Outdoor Theatre	Drive Ins	400 Inch	1990-95	Y 2.5 billion
Outdoor Theatre Billboard Advertising	Side Walls of Buildings	400 Inch	1990-95	Y 2.5 billion
Indoor Theatre	Movies	400 Inch Rear Projection	1989	Y 250 million to Y 500 million
Indoor Minitheatre	Department stores Hotels	100 Inch Rear Projection	end 1988	Y 80 million to Y 240 million
Indoor Minitheatre	Restaurants Coffee Shops	100 Inch Rear Projection	end 1988	Y 80 million to Y 240 million
Street Bulletin Board	Parks, Lots Streets	100 Inch Rear Projection	1990-95	Y 30 million to Y 70 million
Moveable Bulletin Board	On cars for advertisements	100 Inch Rear Projection	1989	Y 40 million to Y 100 million
Broadcasting Conference System	Offices, Factories	Two 50 Inch	1990	Y 13 million to Y 220 million
Broadcasting Conference System	Universities, Training courses	Two 50 Inch	1990	Y 13 million to Y 220 million
Satellite Broadcasting	Consumer Home Use	40 Inch MUSE Receiver	1990	Y 3 million to Y 20 million
Ground Broadcasting	Consumer Home Use	40 Inch MUSE Receiver	1990	Y 3 million to Y 20 million
High Vision Database	Libraries Art Museums Hospitals/ Health Centers University Research Institutes Government Offices Fire Stations City Halls Showrooms Railroad Stations	50 Inch	1988	Y 80 million to Y 140 million

Sources: MPT High Image City Council Draft Planning Report, "Toward an Affluent High Image [Vision] City by High Vision [Technology]," translated from the Japanese by the Congressional Research Service (1988). The original table contained additional information about the systems that would be used in each instance and the technical problems facing their use.

procurement company (it has not been given a name) would stimulate the use of direct satellite broadcasting by reducing its costs (Ref. 5.61).

*MPT and the HDTV Satellite Corporation.* MPT, the National Space Development Agency (NASDA), Japan Satellite Broadcasting Company (JSB), and NHK are supporting the development and launching of three satellites that are needed for the transmission of HDTV by direct broadcast satellites (DBS). The BS-3 satellite is being developed with financial assistance from the Japanese Ministry of Finance through a special account that has invested 2 billion yen in the HDTV Satellite Corporation. The Corporation owns the rights to use one of the three transponders and also leases the right to use this transponder to major broadcasters. The HDTV Satellite Corporation collects fees from users who lease the transponder. NASDA is paying 35 percent of the cost of the leasing for the BS-3 satellite, with the remainder coming from fees paid by NHK and JSB (Ref. 5.62).

The BS-3 satellite was developed by the Science and Technology Agency. Figures from the FY 1986 budget (translated in 1990) show that the development effort was supported by 1.425 billion yen, compared to 2.172 billion yen in FY 1985. The BS-3 satellite project has been overseen by the National Space Development Agency (Ref. 5.63).

JSB is a satellite broadcasting company that was established in 1984 and is the sole provider of current foreign movies for pay TV programming by DBS in Japan. It is owned by 194 companies. Its major shareholders include all the commercial TV networks and newspaper publishing companies. Its broadcasts will start with a low-power, one-channel satellite, the BS-3a, to be launched in August 1990. Broadcasts will expand, once a multichannel, high-power satellite is launched in 1993. For the BS-3a satellite, JSB is providing 20 percent of the cost of the satellite's launch and manufacturing, or 15.4 billion yen. The remainder of the cost is covered in part by 26 billion yen from other private broadcasters, manufacturers, and trading firms (Ref. 5.64).

### **The Key (or Basic) Technology Research Center**

The Key (or Basic) Technology Research Center, known also as the Key Technology Center (KTC) was established in 1985 by both MITI and MPT. The legislation that provided for the establishment of this center was the Basic Technology Research Facilitation Law of June 15, 1985. The Key Technology Center was a compromise between competing efforts by MITI and MPT to establish new agencies to promote and finance high technology industries. In 1984, MITI had proposed establishing "a new agency under its jurisdiction and funded, in part, by the Japan Development Bank to promote and finance high technology industries. About the same time, MPT, seeking a public agency to

provide continuing support for NTT's joint R&D projects after NTT's 'privatization' advanced a proposal to fund such an organization through the use of dividends paid on NTT shares still held by MPT. [The Ministry of Finance]...proposed to fund the new entity by reviving the Industrial Investment Special Account, an unconsolidated account which had been used as an industrial promotion tool in the 1950s and 1960s" (Ref. 5.65). After extensive wrangling between the agencies, the Japan Key Technology Center was created.

The Key Technology Center has the power to make low-interest, high-risk loans by assuring that 7.1 percent loans are available to companies "successful in ... developing and marketing R&D projects" (Ref. 5.66). If these R&D commercialization efforts fail, the loans do not have to be repaid. In addition, the Center funds "joint companies," or consortia, that are established by a number of companies to support cooperative, precompetitive research. One focus of the Key Technology Center's efforts is to be the long-range projects that are of particular interest to the public welfare, but which are unlikely to show a profit in a short time frame. The Center was also created with the intention that it would improve the cooperative research efforts of the 16 government labs managed by MITI, MPT, and private companies (Ref. 5.67).

The Key Technology Center's mission is "to promote basic research in the key technologies needed for the leap to the next-generation industries" (Ref. 5.68). It funds riskier technology firms or consortia exploring the commercial potential of new technologies, acting as an investment banker. It is different from previous Japanese national research projects in that it receives its funds from the Japan Development Bank, private industry, dividends from the sales of NTT and Tobacco Corporation stock that are held by the government, and dues paid by government banking institutions. By comparison, MITI's funds for national research projects come directly from the national budget (Ref. 5.69).

The Key Technology Center is managed jointly by MITI, MPT, and the Ministry of Finance. Dividends from government-owned stock in NTT and Japan Tobacco, Inc. were allotted to a new industrial investment special account. Funds from both this account and the Japan Development Bank are utilized by the Center. In addition, loans and treasury investments from the Center are used to underwrite an International Telecommunications Basic Technology Laboratory and the Teletopia Promotion Foundation. In FY 1986, these treasury investments and loans were more than doubled, increasing to 101.7 billion yen over the amount for FY 1985 (Ref. 5.70).

In 1988 and 1989, three significant projects related to HDTV were funded as R&D consortia by the Key Technology Center. This lends some support to the notion that they are to develop "key technologies" that the government believes

are crucial to Japan's future. The projects are the Giant Technology Corporation for the development of 40-inch diagonal flat panel displays; the High Definition Television Engineering Corporation (or Hi-Vision Technology Laboratory), and the Graphics Communications Technology Corporation (Ref. 5.71). The funding for these projects is summarized in Table 5.8. Funding for the loans that KTC has made since 1985 are summarized in Table 5.9.

*The Giant Electronics Technology Corporation (GTC).* The most significant initiative proposed to support the commercial development of HDTV has been the Giant Electronics Concept (GEC) or Giant Technology Project announced by MITI in the Fall of 1989 (Ref. 5.72). This proposal was never adopted. However, in modified form and with far less funding than was originally advocated, the Giant Electronics Technology Corporation (GTC) was launched by the Key Technology Center. The original proposal for the GEC was for a seven-year, 13 billion yen (\$89.6 million) project; for the GTC, the funding level has been changed to 2.8 billion yen (\$20.7 million at 135 yen to the dollar), with an initial capitalization of 390 million yen (Ref. 5.73).

The goal is the development of a one-meter-square liquid crystal flat panel color display for TV, copier, and large-area image reading applications. The technical developments required to achieve this goal include "large-area, ultra-thin glass plates, liquid crystals with high-speed response, high-speed polysilicon thin film transistors, large area color filters, and a technique for uniformly inserting liquid crystal between glass plates" (Ref. 5.74). The Key Technology Center was to pay 70 percent of the investment in GTC (Ref. 5.75).

The GTC includes 17 companies, many of which were announced as participants in the consortium proposed by MITI. They are divided into two groups: core companies, which are the main participants and are more involved in setting the goals of the consortium; and consortium members. The core companies of the GTC include Dai Nippon Printing, Hitachi, Sharp, NEC, and Toppan Printing. The members include the Key Technology Center, Asahi Glass, Casio Computer, Chisso, Fujitsu, Hoechst Japan, Japan Synthetic Rubber, Nippon Sheet Glass, Sanyo Electric, Seiko-Epson, Semiconductor Energy Laboratory, Thomson Japan, and ULVAC Japan (Ref. 5.76).

This consortium is noteworthy for its inclusion of companies from a wide range of industries, such as electronics, glass, printing and liquid crystal materials. Under its new form, the GTC also appears to have a much broader mission than was originally envisioned by MITI. The initial proposed mission of the GEC was to develop various fundamental technologies that are needed to achieve a commercial display that is one-meter square by 1996. While Japanese firms have been steadily increasing the size of their flat panel displays, the GEC was envisioned as a way to facilitate the technical

Table 5.8

**KEY TECHNOLOGY CENTER GRANT PROGRAMS FOR HDTV**  
(billions of Yen)

	Years for Program	Companies Involved	Total Budget
<b>GRANT PROGRAMS</b>			
Giant Technology Corporation	1988-1993	17	2.8
High Definition Television Engineering Corporation	1988-1993	3	3.4
Graphics Communications Technologies, Ltd.	1986-1990		2.4
			—
<b>TOTAL</b>			<b>8.6*</b>

\*At 135 yen to the dollar, this is equal to \$63.70 million

The totals given in this table are for the entire project, i.e. the contribution from the Key Technology Center, which usually provides as much as 70 percent of the entire project costs, and the private industry contribution of 30 percent. In several instances, the total project amounts have been estimated by assuming that the Key Tech Center accounts for 70 percent of the total budget. This may result in underestimates for the figures for the total budget for projects begun prior to 1988.

Sources: J.G. Parker and E.J. Vardaman, *Japanese Developments in High Definition Television*, TechSearch International, Inc., September 1989:48-49; GTC Corporation, "Company Profile," provided by the Key Technology Corporation to members of an official delegation, May 1990; and TechSearch International, Inc. compilation from Key Technology Center Documents, April 1990.

Table 5.9

**KEY TECHNOLOGY CENTER LOAN PROGRAMS FOR HDTV**  
(millions of Yen)

LOAN PROGRAMS	Initial Year for Program	Budget	
		First Year	Total
HDTV-Related Technologies	1985	343	441
Next-Generation Moving Image Bandwidth Compression	1985	255	485
High-Speed Digital Transmission and Storage for HD	1986	37	53
Low-Voltage Driven Electroluminescent Display	1987		57
Color Filter for Large LCDs	1987		27
Image Communications Terminal	1987		26
Digital Animation Store-and-Forward Technology for Broadcasting	1988		56
Ultra-High Speed Analog/Digital Signal Processing Systems	1988		42
Large Surface Projection Systems	1988		15
Heteroepitaxy on Large Surface Glass Substrate	1988		11
TOTAL OF ALL LOANS 1985-1988			1213*

\*At 135 yen to the dollar, this is equal to \$8.99 million

Source: TechSearch International, Inc. compilation from Key Technology Center documents published in Japanese, April 1990.

breakthroughs needed to reach the proposed goal of a one-meter-square flat panel display. However, the mission of the GTC is to carry out "research and development on the basic technology of giant electronics" (Ref. 5.77).

In a 1990 company profile of the GTC, the technologies that are to be the focus of the GTC's activities are identified as: (1) higher mobility polysilicon circuitry developments; (2) large area polysilicon film fabrication technologies; and (3) large area and higher resolution patterning technologies. These technologies are to be developed to make it possible "to fabricate millions of thin film active elements on the large area substrate," primarily glass (Ref. 5.78).

As noted in Figure 5.5, once these technologies were developed, it would be possible to fabricate the large area circuitry elements needed for flat panel displays. However, what differs from the original concept of the project are the applications specified in Figure 5.5, which link the development of this range of technologies to a much broader range of industries. These applications had been suggested to the JTEC panel at various points in our visit to Japan, but no single program had crystallized the final applications in as clear a manner as they are now presented for the GTC.

*High Definition Television Engineering Corporation.* The High Definition Television Engineering Corporation (HDTEC), also known as the Hi-Vision Technology Laboratory, Advanced Image Technology Research Laboratory, or the High-Level Video Technology Research Center Inc. (*Kodo Eizo Gijutsu Kenkyujo*), was established in April 1989 by KTC, NEC, Seiko-Epson, and Meitec. The consortium is to develop liquid crystal display technologies and the processing capabilities needed for these displays to be used by consumers, as in computer displays and other applications. Initial plans earmarked approximately \$75 million for the consortium over four years (Ref. 5.79), but it is now clear that the initial capitalization of the corporation is set at 3.4 billion yen (\$25 million) (Ref. 5.80). Additional funding for the Center will come from NHK and the Railway Integrated Technology Research Center (Ref. 5.81). It is expected that the corporate participants in the consortium will invest much larger amounts in the development of process equipment (Ref. 5.82).

The main research areas that HDTEC will pursue are: (1) the use of computer graphics to create high-speed, high-efficiency HDTV images; (2) the development of digital transmission technologies for optimizing the connection of HDTV systems to broadband ISDN networks; (3) advances in liquid crystal projection display technology; and (4) techniques to create and evaluate HDTV liquid crystal projection displays (Ref. 5.83).

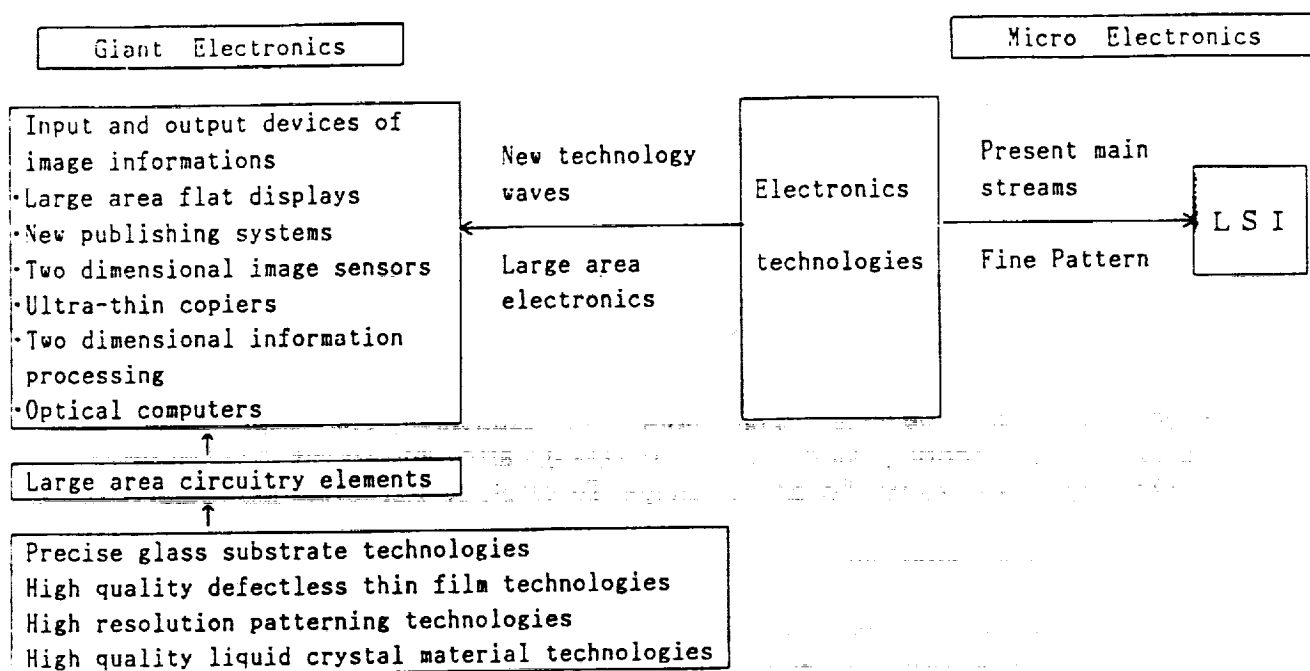


Figure 8.8. Applications of Technologies to be Developed by the Giant Electronics Project

Source: GTC Corporation, "Company Profile," provided by the Key Technology Corporation to members of an official U.S. Department of Commerce delegation, May 1990.

HDTEC was announced in 1989 as a Key Technology Center-sponsored corporation. This joint venture will produce liquid crystal display rear-projection television sets that have screen sizes of 50 inches or larger. The corporation will have 70 percent of its startup costs of \$2.8 million paid by the Key Technology Center (KTC) (Ref. 5.84). The remaining costs will be covered by the private-sector members of the venture, Seikosha Epson, NEC, and Meitec. Over a five year period, investment by the KTC and the private members of the joint venture in the company is expected to total more than \$26 million. Seiko, which has already developed these displays (see Chapter 4), and NEC will develop and refine the LCD projection system, with NEC also taking the responsibility for developing the interfaces necessary for tying the HDTV into the integrated services digital network for future optical transmission applications. This will permit HDTV to be transmitted digitally. Meitec is a software firm that will be doing research on the computer graphics needed for HDTV applications in HDTV broadcasting and commercials, as well as in high definition industrial CAD/CAM systems. While NHK has no capital invested in the company, it is to evaluate the results of the HDTV Engineering Corporation's development efforts (Ref. 5.85).

The work of HDTEC is being carried out in four centers. The center at the Seiko-Epson Laboratories in Nagano Prefecture is working on rear-projection liquid crystal displays. The second center, located in Kawasaki, is led by NEC Home Electronics and is focusing on transmission techniques, including International Standard Digital Networks (ISDN) and broadband networks. Under the leadership of Meitec and the former Japan National Research Laboratories, the third center is focusing on software for HDTV graphics. At the fourth center, the NHK Research Laboratories, NHK is evaluating the picture quality of liquid crystal displays for HDTV. HDTV Engineering Corporation is doing additional work on bandwidth compression, and is also addressing the question of how to shorten the time needed to refresh HDTV screens, a problem because of the five- to six-fold increase in the amount of information displayed (Ref. 5.86).

*The Graphics Communications Technology Corporation.* The KTC-sponsored Graphics Communications Technology Corporation will develop a technology that is primarily for use on computers, but which will provide one means for computers and television to be merged. Its budget in its first year of operation was \$5 million, with the budget covering its four-year life set at \$16 million (Ref. 5.87). The consortium will develop programs that permit three-dimensional data to be processed and programs for image processing to be used in communications systems. It will also create subsystems for use in processing images. The technology being developed by this consortium is likely to be applied in "TV telephone systems, factory automation, education, publishing,

environmental sensing and measurement, CAD/CAM, and several other areas" (Ref. 5.88).

### **NHK, Japan Broadcasting Corporation**

The Japan Broadcasting Corporation, *Nippon Hoso Kyokai* (NHK), has played an important role in promoting the development of HDTV. NHK is similar in size and scope to the British Broadcasting Company. It raises 97 percent of its revenues from subscriber fees and has an annual budget of \$2.8 billion for broadcasting, about a quarter of the total for the broadcasting industry in Japan. This includes about \$20 million annually that is spent on NHK's laboratories (Ref. 5.89).

NHK has played a pivotal role in developing technologies for HDTV, transferring many important innovations to private firms at little or no cost to them. It has also formed a number of consortia that have developed and perfected HDTV technology that has proven invaluable to private firms. Estimates have placed the value of NHK's R&D as high as \$500 million (Ref. 5.90), although the figure disclosed by NHK is 20 billion yen (\$148 million at 135 yen to the dollar) over the 1964-89 period, not including contributions made by private corporations (Ref. 5.91).

NHK financed the initial development of HDTV in Japan. NHK also pioneered work on direct satellite broadcasting and the digitizing of signals. In 1978, NHK launched an experimental medium-scale broadcast satellite that was used to develop techniques for transmitting luminance, color, and FM audio signals (Ref. 5.92). NHK's research labs also developed the MUSE compression system that was needed to make commercial broadcasting more feasible. Private manufacturers, such as Toshiba, NEC, and Matsushita, joined the NHK efforts about six or seven years ago. The Japanese government has estimated that these firms have spent as much as \$400 million on the development of HDTV products (Ref. 5.93).

NHK's most important work has been done through "development teams" that are based upon the model established by NTT, that is, a family of companies receive the specifications for a new product, jointly develop the new product, and then manufacture it. For instance, in the development of NHK's MUSE decoder chip set, Toshiba, NEC, and Matsushita were part of the initial NHK-led effort and were then joined by Hitachi and Sharp (Ref. 5.94).

NHK has had several reasons to be interested in HDTV development. First, HDTV is likely to attract more viewers once it becomes more affordable for consumers, providing a basis for more funding for NHK's own activities.

Second, the move to HDTV is likely to result in better movies, making NHK's film programs more attractive to its subscribers.

According to NHK representatives, HDTV might enable NHK to gain some advantages over its rival broadcasters in the 1990s. Although NHK is the leading broadcaster today, it foresees substantial new competition with other broadcasters once satellite broadcasting comes into its own. In the spring of 1991, Japan Satellite Broadcasting (JSB) will begin regular satellite broadcasting on one of three channels of the new BS-3a satellite that were launched late in 1990. JSB's 24-hour schedule and offering of the latest films, music events, sports, and entertainment will offer a challenge to NHK (Ref. 5.95).

According to estimates that the JTEC panel was given during a visit to NHK's laboratories, 2.1 million households will be able to receive direct satellite broadcasts by the end of 1989; 50,000 households are being added to this number every month. No satellite receivers for HDTV broadcasts were on the market in 1989; however, the BS-3 satellite that was to be launched in 1990 will have opened the way for the use of HDTV receivers (Ref. 5.96).

The real change in broadcasting competition is likely to occur once a wide range of viewers can receive HDTV. Although the costs for HDTV receiving equipment is currently 3 million to 5 million yen (\$22,222 to \$37,037 at 135 yen to the dollar), it is expected to reach 1 million yen when production volume rises to about 10,000 sets per month, according to an NHK spokesman cited by the *Financial Times* (Ref. 5.97). During the visit by the JTEC panel, the staff of the NHK laboratories stated that NHK's goal was to have a MUSE receiver for HDTV available in Japan that would cost twice as much as a regular TV receiver (500,000 yen compared to 250,000 yen, or \$3,704 vs. \$1,852 (Ref. 5.98).

Although experimental broadcasts are still being offered for only one hour a day, from 2:00 - 3:00 p.m., and two back-up BS-2X satellites for HDTV broadcasts were lost due to an explosion of an Ariane launch vehicle in February 1990, there is still an expectation that NHK will start regular HDTV broadcasts in three to five years. NHK was to operate two of the three transponders of the BS-3a satellite and extend daily broadcast hours in 1990, but it may be forced to continue limited one-hour broadcasts for the next year due to the loss of the satellites. NHK is now dealing with the shortage of programming material for HDTV by reediting existing programs and accumulating other "software" and the rights to broadcast specific programs in anticipation of extended HDTV broadcasting (Ref. 5.99).

NHK is also "involved in an advisory capacity in practically all private consortia and public HDTV programs" (Ref. 5.100). It plays a more active role in innovations in equipment that will be needed for the commercial use of HDTV

than appears to be true from NHK's reputation primarily as a broadcaster. NHK has established five projects that are administered as consortia to develop affordable HDTV receiver sets; one result of these consortia is that NHK offers its technology and expertise to joint development efforts that can help "bring down the price of HDTV receiver sets to 500,000 yen" (Ref. 5.101).

### **Satellite Construction and Launching for HDTV**

An HDTV satellite initiative is being planned to launch two HDTV direct broadcast satellites in 1990-91 as part of a 78.4 billion yen (\$581 million) effort. NHK and JSB will contribute 65 percent of the costs, while NASDA will provide 35 percent. JSB will use the satellites largely for commercial and pay NTSC TV, shifting to HDTV broadcasts later. MPT will lease one channel on BS-3b (Ref. 5.102).

An HDTV Satellite Procurement Corporation that will be established by MPT is to raise 100 billion yen (\$741 million) in capital by 1991-92 to develop and launch a more sophisticated HDTV satellite in 1997. About four HDTV channels would be made available by this satellite. Not until this satellite is launched will HDTV broadcasts be very substantial (Ref. 5.103).

Another indication of the sums spent for satellite broadcasts comes from published figures covering the Ministry of Education's budget. This ministry's program to foster and promote new media, largely in support of DBS, was doubled from 40 billion yen to 80 billion yen in FY 1986. This reflected preparations for the era of large-scale satellites, implemented through increases in funds for basic research promotion at the national testing laboratories (Ref. 5.104). Additional support for MPT's efforts in HDTV has come from other government entities and private sector contributions. The Broadcast Technology Association (BTA) has offered funding to augment MPT programs. Much of BTA's support is channeled to MPT through a loan program for HDTV development that is aided by the Long Term Development Bank and MITI (Ref. 5.105).

## **PROGRAMS TO SUPPORT RELATED TECHNOLOGIES**

### **Communications Programs Related to HDTV**

Table 5.10 lists a number of government and private communications initiatives that are likely to be important to the commercial success of HDTV. These include demonstration projects, such as Teletopia (the establishment of model cities for telecommunications) and the development of an information network system by Nippon Telephone and Telegraph (NTT).

A number of different institutions in the Japanese government are involved in promoting communications initiatives in Japan, including MITI, MPT, the Japan Development Bank, the Science and Technology Agency of the Ministry of Education, and NTT.

*The Information Network System.* The Information Network System (INS) was initiated in 1983 by NTT. NTT's goal is to deploy the fiber-optic trunks, digital switches, and enhanced services throughout Japan that are needed to establish a new generation of digital communications services. INS will be financed entirely by NTT and is expected to cost \$80 billion to \$120 billion over a 10 to 15 year period (Ref. 5.106).

INS has been described as "a set of services delivered by a comprehensive value-added network with all protocol layers represented and all application level functions implemented within the single network" (Ref. 5.107). INS will replace an old tariff structure based on connect time and distance with a "pay-by-the-bit" structure. The network will have one "fabric" that is based entirely on digital technology for voice, data, and video. According to telecommunications specialist Paul Green, "INS...will probably succeed modestly well as a national communication fabric and as a truly integrated network, but will succeed even better at giving the Japanese an edge in understanding and developing products for future telecommunications-based applications" (Ref. 5.108).

NTT established an INS model system from September 1984 to March 1987 in order to determine the relative popularity of services. This experimental network provided a way to explore how NTT could make INS services as accessible as possible. The functional capabilities of INS were analyzed and the social implications and impact of INS were evaluated. The model system was a 64 Kb/s network for digital phone and facsimile services, and a broadband network for video and high-speed data transmission (Ref. 5.109).

Among the new services that are presently being examined in pilot projects are "interactive visual communications networks..., integrated voice-data and voice-video equipment, optical scan document terminals and fast mini-faxes, and optical instrumentation and control systems for industrial and office applications" (Ref. 5.110).

INS is relevant to HDTV commercialization since it would provide opportunities to use the advanced imaging instrumentation and control systems more widely

Table 5.10

**JAPANESE COMMUNICATIONS AND COMPUTING INITIATIVES  
WITH CLEAR POTENTIAL TIES TO HDTV PROGRAMS  
(Annual Spending, Billions of Dollars)**

Information Network System	\$ 8.57
Teletopia	2.0 estimated
MITI's Global Factory Plan (MITI-10 years)	.33
New Communications Protocols	.21
Interoperable Database Systems	.10
New Information Processing Technology	?
<b>Total spending</b>	<b>\$ 19.92 Billion</b>

Sources: William H. Davidson, "The Japanese Telecommunications Industry: Policy, Structure and Performance," in National Science Foundation, Japanese Technology Evaluation Program, "JTECH Panel Report on Telecommunications Technology in Japan," May 1986, p. 2-23; Paul E. Green, Jr., "Networks," in National Science Foundation, Japanese Technology Evaluation Program, "JTECH Panel Report on Telecommunications Technology in Japan," May 1986, pp. 3-22 to 3-23 and 3-37; William H. Davidson, "Trends in Telecommunications Networks: Regulatory Issues and the Outlook for the U.S. Information Economy," FCC Docket #87-313, September 9, 1988, Appendix I; William H. Davidson, "Telecommunications Policy In Global Perspective," FCC Docket #87-313, p. 22 as cited in Campbell, Supplemental Comments Submitted to the Telecommunications & Finance Subcommittee of the House Energy and Commerce Committee, August 30, 1988, p. 4; "Main Electronics Projects in Government Budget for FY 1986," *Nikkei Electronics*, May 8, 1986, pp. 265-269; and Hisayuki Mitsusada, "Japan seeks U.S., Europe cooperation in plan to create computer-linked factories," *Japan Economic Journal*, July 15, 1989, pp. 1, 4.

in industrial and office settings by making large bandwidth networks available to corporate customers. INS would also accelerate the broadcasting of HDTV over fiber networks.

*The Teletopia Program.* The Teletopia concept, establishing model cities that focus on new media, was initially planned as a \$150 billion project over the 1986-2000 period to provide new infrastructure for cities that would enable consumers and industry to use HDTV and other advanced communications services. Tsukuba Science City served as the experimental base for studying how cities would participate in the development of new media. In FY 1986 feasibility studies were begun on how to make the Teletopia concept operational in other cities, aided by some of Japan's leading telecommunications firms. The number of model cities was increased to 53 in FY 1986. In the initial FY 1986 budget, treasury investments and loans to support the Teletopia program were doubled to 101.7 billion yen, including the 80 billion yen budget for fostering and promoting new media. However, the Teletopia effort is presently blocked by political disputes between MPT and MITI. Although the outcome is unclear, it is unlikely that more than \$2 billion a year is being spent on activities that are "Teletopia-like" (Ref. 5.111).

Once the present conflict is resolved, funding for a Teletopia program would be likely to come from funds for "fostering and promotion of new media" established through a special fund in the MPT budget, or from other funds for the promotion of telecommunications infrastructure research. At the present time, the best estimate of spending on Teletopia programs is that about \$2.0 billion is being committed through loans from Japan Development Bank, with an additional \$150 million coming from Key Technology Center programs to promote new media and communications infrastructure (Ref. 5.112).

#### **Industrial Programs Related to HDTV**

*MITI's Global Factory Plan.* In July 1989, MITI announced a Global Factory Plan to spur the international use of computer-integrated manufacturing (CIM) techniques. The goal of this effort is to develop "an intelligent manufacturing system (IMS) that would standardize factory operating systems around the world so that different manufacturers' robots and computer information systems could be integrated" (Ref. 5.113). This initiative is key to an understanding of Japan's efforts to promote HDS. The Global Factory program will support the development of fiber optic networks to link various plants within a single company. Once such networks are in place, they will make it easier to use HDS in factory environments (Ref. 5.114).

This program has not yet been approved because the Japanese government has sought to make it an international cooperative project, but has not been able to

gain U.S. support for it; however, the planned 10-year, 50-billion yen program has the potential of spurring the installation of valuable, firm-level computer-aided design/computer-aided manufacturing (CAD/CAM) systems in corporate design divisions and flexible manufacturing in corporate production divisions. These divisions are exactly where Sony and other firms plan to market HDS for industry most aggressively over the next few years (Ref. 5.115). Indeed, the volumes describing HDS products that the JTEC group had a chance to see while we were in Japan emphasized these very areas of use. Thus, the MITI effort would tie directly into the promotion of these systems for sale to large manufacturing companies (Ref. 5.116).

*MITI's Interoperable Database Systems.* The Interoperable Database Systems Project is conducting R&D "on technology for interoperable information systems with such features as distributed databases and multi-media technology, to form an infrastructure for the 'information-oriented society' (Ref. 5.117). Its emphasis on multimedia technology is likely to include uses for HDTV in intelligent manufacturing. This project was begun in 1985 by MITI's Agency of Industrial Science and Technology (AIST) as a "Large-Scale Project," or National Research and Development Program, an R&D project which is "of particular importance and urgent need to the nation." (25 AIST projects have been given this designation since 1966) (Ref. 5.118). This project is scheduled to be completed in 1991.

#### **MITI's New Information Processing Technology Project**

In April 1990, MITI announced its New Information Processing Technology Project, a major new initiative that may be classified as a "Large-Scale Project." While primarily for advanced computing models that will represent intuitive thinking, this project does include goals such as better "man-machine collaboration" for intelligent control of production (Ref. 5.119). At the present time, there is no information about the size of the project.

### **THE ECONOMIC RATIONALE BEHIND JAPAN'S POLICIES FOR HDTV: THE IMPORTANCE OF CREATING LINKAGES BETWEEN HDTV, ELECTRONICS, COMPUTERS, AND COMMUNICATIONS**

#### **Japan's Use of Input/Output Techniques for Economic Forecasting and Analysis**

Japanese policies for HDTV and for the electronics industry appear to be derived from insights gained from the use of economic input/output techniques. Although these techniques are not widely used, they are well recognized by professional economists. They allow planners and policy makers to identify some of the significant interdependencies that exist in an economy or in specific groups of industries, such as the links between electronics, computers, and communications equipment. These techniques were originally developed

by Professor Leontief of New York University to utilize the simple economic fact that all industries use inputs from other industries to create their final products; thus, a large number of industries supply their outputs to other industries that use these inputs to produce final goods or other intermediate goods. In economic terms, input/output analysis emphasizes the linkages that are established by the successful development of scale economies and spillover effects (Ref. 5.120).

Two tables from *MITI Vision for the Year 2000* (Tables 5.11 and 5.12) illustrate how input/output analysis works. The input/output structure of the economy changes over time; by estimating how industries that act as purchasers change their requirements for goods produced by selling industries, it is possible to estimate how the interdependencies among sectors will change.

Examining these changes and how they spread throughout the economy enables Japan's government and industry to evaluate the "driving" technologies for the future. It also permits both government and industry to shift valuable resources to these sectors and away from declining sectors ("sunset industries"). Input/output techniques also describe the linkages that become more or less important as one sector expands and others grow less rapidly or contract.

In the case of the tables from the MITI Vision document, the total domestic production of the electronics industry is expected to grow from 27.7 trillion yen (\$205.2 billion at 135 yen to the dollar) to 228.9 trillion yen (\$1.696 trillion) between 1984 and 2000.

One important feature of this expansion is that the gross value added, or production value added by manufacturing within the electronic sector, grows dramatically from 1984 to 2000, from 8.7 trillion yen (\$64.4 billion) to 50.5 trillion yen (\$374.1 billion), a nearly six-fold expansion. This growth is related to a large increase in the consumption of electronics goods in domestic markets and through foreign sales. This expansion can be seen in the column labeled "total final consumption," which grows from 17.2 trillion yen (\$127.4 billion) in 1984 to 148.7 trillion yen (\$1.1 trillion) in 2000.

The first column of each table permits the reader to compare the purchases of inputs from other industries with sales to the electronics industry itself. In 1984, the electronics industry purchased 8 trillion yen, or about 29 percent of its domestic production from itself, while in 2000, it is expected to purchase 41 trillion yen, or 18 percent of its total production from itself, according to projections using input/output tables created for the year 2000. This result indicates that the electronics sector is in the process of creating greater

Table 5.11

## 1984 INPUT-OUTPUT TABLE

Unit: 100M¥

Seller \ Buyer	Electronic Industry	Telecommunications	Information Services	Other Industry	Sub Total	Total Final Consumption	Domestic Production
Electronic Industry	80,274	6,345	3,363	15,173	105,155	171,918	277,073
Telecommunications	2,095	730	413	30,910	34,148	15,409	49,557
Information Services	1,653	187	1,028	26,975	29,843	196	30,039
Other Industry	106,297	3,921	6,979	3,066,820	3,184,017	2,881,273	6,065,290
Sub Total	190,319	11,183	11,783	3,139,878	3,353,163	3,068,796	6,421,959
Gross Added Value	86,754	38,374	18,256	2,925,412	3,068,796		
Domestic Production	277,073	49,557	30,039	6,065,290	6,421,959		

NOTE: Total Final Consumption: (Consumption, Capital formation, Inventory Increases, Export-Import)

Source: MITI Vision for the Year 2000 as cited in V.N. Cook and D.J. Sullivan, "Perspective on Japan," presentation for the Defense Science Board, Aspen, Colorado, July 20, 1988.

Table 5.12

## 2000 INPUT-OUTPUT TABLE

Unit: 100M¥

Buyer Seller	Electronic Industry	Telecommuni- cations	Information Services	Other Industry	Sub Total	Total Final Consumption	Domestic Production
Electronic Industry	407,330	36,401	84,797	273,740	802,268	1,486,619	2,288,887
Telecommuni- cations	16,731	3,800	8,010	47,858	76,399	108,993	185,392
Information Services	36,072	1,733	29,855	109,531	177,191	209,042	386,233
Other Industry	1,323,459	6,557	48,763	4,609,568	5,988,347	5,169,458	11,157,805
Sub Total	1,783,592	48,491	171,425	5,040,697	7,044,205	6,574,112	14,018,317
Gross Added Value	505,295	136,901	214,808	6,117,108	6,974,112		
Domestic Production	2,288,887	185,392	386,233	11,157,805	14,018,317		

Source: *MITI Vision for the Year 2000* as cited in V.N. Cook and D.J. Sullivan, "Perspective on Japan," presentation for the Defense Science Board, Aspen, Colorado, July 20, 1988.

linkages to other sectors which will result in more numerous opportunities for spillover effects in the Japanese economy. These spillover effects will enhance the technology and production processes available to other industrial sectors.

These changes give us a thumbnail sketch of some of the linkages that are created between industries whose growth is very dependent upon electronics and information processing. They provide policy makers and industry with very useful insights into the changes that are likely to occur in an advanced economy over time. As a consequence, more informed decisions can be made about investment and the support of basic research and commercial development.

MITI has used such information to develop its plans to restructure the Japanese economy and to promote a shift in Japan's industrial base to more high-value-added industries. In order to take advantage of such a restructuring, the new activities would have to be developed by domestic firms which would help the technological knowledge embodied in new products diffuse throughout related industries and permit the economy to gain the most from learning about new process and new product skills. If domestic firms were unable to provide such benefits to other industries or had to purchase such leading technology products from abroad, the reliance on foreign advanced technology would not contribute to the expansion of domestic production, nor would the larger economy gain from the dynamic externalities that come from new technology industries that create greater amounts of added value--i.e., greater profits (Ref. 5.121).

In addition, as the Japanese shift the base of their economy from markets for mass-produced export goods to sophisticated electronics-based products and services, they need to develop the infrastructure to support an information-based economy. Massive investment in domestic infrastructure is required in order to gain the "Big Bang" type of economic advances that the economist Paul Rosenstein-Rodan postulated were possible in certain unique occasions in economic development. Such advances represent another type of indivisibility that is not dealt with effectively by traditional economic analysis. It would appear that HDTV and the substantial changes that it can bring about in a number of related industries create a situation where massive reordering can take place in an economy, bringing with it huge benefits in terms of growth and consumption (Ref. 5.122).

### **The Outlook for Japan's Efforts to Develop HDS**

It is possible to gain some idea of the direction that Japanese development of HDS will take by examining a recent report by the Japanese Science and Technology Agency, entitled *Future Technology in Japan* (Ref. 5.123). This

study of future technologies queried 3,000 Japanese specialists in a number of technology industries (including company research scientists, government technology experts and academics) about scientific and technological developments over the next 35 years. The report identifies which new technologies can lead to innovative new products and how much government support is believed necessary to develop successful commercial products. Some selected results from the survey are presented in Table 5.13.

The main areas related to HDS development that are emphasized by this "Delphi" study are flat panel display development, advanced communications links, the creation of the electronic office, and advanced imaging technology. In seven of the ten areas listed in Table 5.13, the respondents believed that the area was of medium to high importance. Most of these new products will be developed near the end of the next decade. In the case of three product areas, use of HDTV with 1,125 scanning lines, the widespread use of broadband communications for information retrieval, and enhanced communications links between headquarters and branch offices, the respondents believed that there would be economic constraints on commercialization. In the case of three other areas--practical use of displays that read like paper, the development of a three-dimensional TV visible without glasses, and the development of a technology to distinguish complex two dimensional patterns--technology constraints were considered to be the main limits to commercial development.

All of these technology-based products go beyond the high definition systems that are available today. For the most part, they appear to indicate that in the future, the development of software for more advanced HDS and of software to link voice, video, and data communications will be a top priority in Japan.

## **CONCLUSIONS**

### **Likely Growth Trends for HDTV and HDS**

Japan's leading electronics corporations and the Japanese government appear to believe that high definition systems will create a vast market for substantial growth in new information systems (Ref. 5.124). They are investing substantial amounts in R&D to commercialize HDS and HDTV. They also appear to believe that government financing for the early stages of HDS development is very important to assure that private funds are forthcoming for the first stages of commercialization. Government funds also support the development of key technologies needed for HDTV to be successful, such as flat panel displays, digital recording technologies, and networking software. The presence of government funds in Japan reduces the early-stage risks faced by the largest

Table 5.13

**FUTURE TECHNOLOGY DEVELOPMENT IN JAPAN THAT IS RELATED TO  
HIGH DEFINITION SYSTEMS:  
RESULTS OF DELPHI STUDY COVERING PERIOD 1987-2015**

<u>Area to be Developed</u>	<u>Medium-High Degree of Importance</u>	<u>Time of Realization</u>	<u>Constraints on Realization</u> <u>Economic Technology</u>		<u>Need for Government Funding</u>
Widespread Use of HDIV With 1,125 Scanning Lines	86%	1993-1998	76%	7%	15%
Practical Use of Color Image Panels with a Resolution of the Order of 1000 by 1000 Pixels for Use in Portable TVs	36%	1993-1998	43%	52%	21%
Practical Use of Displays that Can be Read Like Print on Paper	88%	1994-2004	14%	77%	24%
Practical Use of Color Video Display Panels with a Resolution of at Least 2000 by 2000 Pixels	93%	1992-1998	32%	62%	24%
Widespread Use of Flat Color TV Screen Size of at Least 20 Inches	90%	1994-2001	45%	48%	18%
Development of Three-Dimensional TV that Can be Viewed Without Special Glasses	59%	1995-2005	18%	74%	20%
Development of Technology to Distinguish Complex Two-Dimensional Patterns at a Speed and on a Par With Humans	94%	1997-2008	4%	94%	39%
Widespread Use of Communications Systems for Retrieval of Still or Motion Video Information from Electronic Libraries Through Broadband Communications Lines	94%	1996-2005	84%	8%	29%
Communications Links to Enhance Links Between Headquarters and Branch Offices Using Entire Wall Surfaces as Displays	48%	1993-2001	73%	16%	17%
Widespread Use of Electronic Systems for all Office Activities, Including Storage, Retrieval, Editing and Preparation of Documents and Statistics	97%	1992-1998	70%	8%	13%

Note: Percentage Scores Represent the Opinion of Respondents Considering the Area Important for Development

Source: Science and Technology Agency, *Future Technology in Japan: Forecast to the Year 2015*. (Tokyo: Institute for Future Technology, September 1988). Published in English as a translation of the original, *Nihon no Gijutsu*, 1987-2015.

corporations and makes it possible for them to take a longer-range view of technologies that may not appear to have clear commercial applications. Government support makes greater risk-taking and more creative analysis of technology trends more rewarding.

The growth of the new high definition systems market, as it is referred to here, will initially be supported by sales to industrial customers. Only later will a more mass market for consumers grow. In the early years of HDS use, corporations are likely to develop sophisticated controls for design, engineering, and production or service-delivery processes. These innovations will rely upon high resolution displays in digital information systems. These advances will create new market opportunities for firms that develop products, networks, software, and services that are wanted by largest manufacturing and service firms.

Thus, the development of HDTV is likely to enhance the interdependency among some of the most dynamic parts of Japanese industry and promote further vertical integration of the largest Japanese electronics firms, particularly those that are planning to offer consumer HDTV products. This will reinforce the efforts of leading ministries to establish the way for even more revolutionary electronics products in the future, as the recent work of Japan's Science and Technology Agency suggests (Ref. 5.125).

Although the loss of two BS-2X satellites early in 1990 may delay commercial broadcasting of HDTV, it is unlikely to affect the push to utilize HDTV in industrial, educational, and medical settings.

### **The Role of HDTV in Transforming the Japanese Economy**

Discussions with Japanese government agencies and with leaders of major corporations during the visit of the JTEC panel have made it apparent that they view HDTV as the center of a move to a vastly different Japanese economy. If Japan's firms are successful in dominating the information markets, they will increase their dominance in the electronics markets because of the great demand that new information products, such as HDTV, will create for advanced memory chips, the large-capacity semiconductors now being developed by the main participants in the chip industry.

Although such a transformation of the economy is not accepted by a majority of economists (Ref. 5.126), its immense potential benefits for Japan's future economic growth have been recognized by Japan's government agencies and its leading corporate managers.

Having a jump on their competitors is a great incentive for Japanese corporations to invest their own funds on the first HDS and HDTV products. Accelerating the development of these technologies is also viewed as a way to gain the lead in products that will result from the convergence of the computer, communications, and consumer electronics markets.

The emergence of HDS/HDTV in Japan could also present a challenge to current American economic thinking. The Japanese use of private sector and government initiatives to promote the industry contradicts the assumption by American policy makers that HDTV will only prove significant to a small market for high-class video (Ref. 5.127).

MITI's announcement in 1989 of proposed large-scale, multi-year programs to promote the commercial development of flat panel displays (the Giant Electronics Corporation, later reduced in scale and developed by the Key Technology Corporation as the Giant Technology Corporation) and to develop an intelligent manufacturing system highlighted a set of crucial issues for HDTV and HDS. The programs to establish a sophisticated fiber optic network in Japan over the coming decade also underscore how important Japan's corporate managers and political leaders view HDTV. In addition, the fiber-optic network that is planned for Japan will provide an environment for Japanese firms to develop new products and services that will be delivered over broadband networks to HDS, computers, and new communications devices.

The Japanese efforts indicate their belief that the role of HDS will have a far-reaching economic impact. Consequently, a careful economic analysis of the Japanese programs to develop HDTV requires economic thinking that appreciates the significance of the strength of "interdependencies" between HDS/HDTV and other electronics and information industry markets.

### **Economic Ramifications of the Japanese Policy Approach**

*Moving Towards an "Electronics-driven" Economy.* It is important that U.S. policy makers recognize the depths of the "Japanese challenge" that is posed by these policies. The new policies suggest that domestic capabilities, such as advanced infrastructure and rapid adoption of emerging technologies in domestic technology-driven industries, are essential for creating advanced technology industries. They break with the old, export-oriented manufacturing policies based on more productive production processes and constitute a shift towards an "electronics-driven" economy that dominates international trade by virtue of preeminence in leading technologies. This is quite different from the findings of the previous NSF Panel on Telecommunications that pointed to the dichotomy between export-oriented funding and the lack of support for domestic improvements (Ref. 5.128).

In addition, Japan's HDTV policies may be indicative of a shift in the Japanese focus on markets for mass-produced export goods to markets for sophisticated electronics-based products and services. This shift requires sizable investment in domestic infrastructure in order to gain the "Big Bang" type of economic advances that the economist Paul Rosenstein-Rodan has theorized are possible in certain unique occasions in economic development. The emergence of HDTV and the convergence that it can bring about in a number of related industries bears certain resemblance to the situation where massive reordering can take place in an economy (Ref. 5.129), bringing with it huge benefits in terms of growth and consumption.

### **The Vertical Integration of Japan's Electronics Firms and Its Influence on HDTV Development**

The strong base that Japan's major corporations have in the consumer electronics industry facilitates their move into high definition systems. Nearly all of the Japanese firms that established a dominant international position in consumer electronics and semiconductors during the late 1970s and the 1980s are major participants in the emerging HDS industry. Table 5.14 shows that the major Japanese electronics firms (NEC, Fujitsu, Hitachi, Toshiba, Oki, Mitsubishi, and Matsushita), all of which are developing HDTV products and services, also have a broad range of capabilities and products in the electronics field. Table 5.15 shows that these corporations plus Sony and the national broadcasting system NHK have a broad range of research in high definition systems that extends far beyond an interest in HDTV. By playing a major role in the consumer electronics industry, these firms have a greater ability to spread the costs of developing new display, semiconductor, and processor products over a large base. By having such a broad range of products that require semiconductors, these firms also benefit from the economies of scale that are significant in their production (Ref. 5.130).

The emergence of Hi-Vision, as the Japanese call it, or of HDTV and high definition systems, appears to be forcing vertically integrated Japanese electronics firms to change their economic behavior. First, they recognize the significance of technological advances in the semiconductor industry as a means to create new product capabilities in consumer and industrial products. Second, they have developed close ties with industrial purchasers that are often the first ones to prove the importance of these new capabilities in products. Third, given the strategic importance of semiconductors in the electronics industry, the Japanese firms place great emphasis on funding innovations in semiconductor technology, even when the economics of the chip industry do not seem to justify the costs. However, the firms that are involved in semiconductor production recognize that the substantial profits that are reaped during upswings in the industry's sales more than make up for the sizable

investments that are made during lean periods, especially if new products that create additional demand for semiconductors are continually being offered to consumers and industry. Thus, there is a dramatic emphasis in Japan on the significant boost in demand for semiconductors that HDS will provide for all of the firms that are involved in HDS development (Ref. 5.131).

The strength of vertically integrated Japanese corporations in the electronics industry also reduces the risks that these firms believe they need to take to develop new products. Cross-subsidization from successful lines of business can provide the investment funds for new products. In addition, risks can be spread by using semiconductors that are developed for one product in another, very different product, making it easier to develop more advanced semiconductors for HDTV that may first see use in VCRs, which have a large consumer market. In addition, major Japanese corporations can achieve economies of scale in semiconductor production because semiconductors are used across a wide range of electronics products, such as VCRs, TVs with more sophisticated picture controls, and digital products, such as CD players.

These strengths in the production of semiconductors affect the economics of developing products with a much longer development time. It is not economically disadvantageous for Japanese corporations to invest substantial amounts in the early development of HDTV, adopting a standard for displays and for production that may not be adopted worldwide, since these firms believe that the basic technological advances that are achieved in developing these new high definition systems can be applied profitably throughout the range of electronics products for computing and communications. In addition, by being the first to have a working HDTV system, these firms appear to expect that the considerable investments that would need to be made by their rivals to catch up would discourage competition from all but the strongest international firms.

Table 5.14

## JAPANESE INTEGRATED ELECTRONICS COMPANIES

PRODUCT/TECHNOLOGY	NEC	FUJITSU	HITACHI	TOSHIBA	OKI	MITSUBISHI	MATSUSHITA
DRAMs	X	X	X	X	X	X	X
SRAMs	X	X	X	X	X	X	X
MICROPROCESSORS	X	X	X	X	X	X	X
ASICs	X	X	X	X	X	X	X
OPTOCHIPS	X	X	X	X	X	X	X
BIOCHIPS	X	?	X	?	?	?	?
SUPERCONDUCTOR	X	X	X	X	X	X	X
3D ICS	X	X	X	X	X	X	X
LAPTOP PCS	X	X	X	X	X	X	X
PCS	X	X	X	X	X	X	X
MINICOMPUTERS	X	X	X	X	X	X	X
WORKSTATIONS	X	X	X	X	X	X	X
AI WORKSTATIONS/CHIPS	X	X	X	X	X	X	X
MAINFRAMES	X	X	X	?		X	
PARALLEL PROCESSOR	X	X	X	X	X	X	X
SUPERCOMPUTERS	X	X	X				
WORD PROCESSORS	X	X	X	X	X	X	X
OFFICE AUTOMATION	X	X	X	X	X	X	X
FACSIMILE	X	X	X	X	X	X	X
DISK DRIVES	X	X	X	X	X	X	X
PRINTERS	X	X	X	X	X	X	X
MODEMS	X	X	X	X	X	X	X
CCR	X	X	X	X	X	X	X
ON-LINE TRANSACTION	X	X	X	X	X		
SWITCHING SYSTEMS	X	X	X	X	X		
SATELLITES	X	?		X	X		
PBX	X	X	X	X	X	?	
OPTICAL SWITCHING	X	X	X	X	X	X	
SOFTWARE	X	X	X	X	X	X	X
SOFTWARE FACTORY	X	X	X	X	X	X	X
EXPERT SYSTEMS	X	X	X	X	X	X	X
MACHINE TRANSLATION	X	X	X	X	X	?	?
AI LANGUAGES	X	X	X	X	X	X	
HEAVY ELECTRIC			X	X		X	
POWER PLANTS			X	X		X	
AEROSPACE	X	X	X	X	X	X	
RAILWAY SYSTEMS			X	X		X	
FACTORY AUTOMATION	X	X	X	X	X	X	X
DEFENSE SYSTEMS	X	X	X	X	X	X	
HOME ELECTRONICS	X		X	X	X	X	X
HOME APPLIANCES	X		X	X	X	X	X
COMPACT DISK	X		X	X	X	X	X
DIGITAL AUDIO TAPE	X		X	X		X	X
MEDICAL ELECTRONICS	X	X	X	X	?	?	?
NEURAL NETWORKS	X	X	X	X	X	X	X
FUZZY SYSTEMS	X	X	X	?	?	X	X
HIGH DEFINITION SYSTEMS	X	X	X	X	X	X	X

LEGEND: X = PRODUCE OR RESEARCH, ? = NOT SURE, BLANK MEANS DO NOT

Source: Mark Eaton, "Japanese High Definition Systems: Research, Development, Deployment," MCC International Liaison Office, Austin, Texas, August 22, 1989.

Table 5.15

## HDS RESEARCH AND PRODUCTS

PRODUCT/TECHNOLOGY	NEC	FUJITSU	HITACHI	TOSHIBA	OKI	MITSUBISHI	MATSUSHITA	SONY	NHK	
CRT DISPLAY	X	X	X	X		X	X	X	X	Ikegami, Sanyo, Sharp
CRT PROJECTION	X	X	X	X		X	X	X	X	Ikegami, Sanyo, Sharp
LCD DISPLAY	HDTV	X	X	X	X	X	X	X	X	Sanyo, Sharp
TFT DISPLAY	X	X	X	X	X	X	X	X	X	
LCD PROJECTION	HDTV									Sanyo, Sharp
HDTV CAMERA (TUBE)			X				X	X		Ikegami, Sanyo, Victor
HDTV CCD CAMERA	X	X		X			X	X		Callo, Ikegami, Sanyo, Sharp.
CCD SENSORS	2M PIXEL			2M PIXEL				X	X	
CCD SCANNERS						X HDTV				
HDTV VTR, ANALOG	X	X	X	X		X	X	X	R&D	Sanyo, Sharp
HDTV VTR, DIGITAL		X	X	X				X	R&D	Canon, Sanyo
VIDEO DISK			X	X			X	X		Sanyo, Sharp, Victor
STUDIO EQUIPMENT				X			X	X		Ikegami
3D COLOR PROCESSOR								X	X	Fuji Television
CONFERENCE SYSTEMS	X	X	X	X	X				X	
TV TELEPHONE	X	X	X	X	X	X	X	X	X	
SATELLITE TRANSMISSION	X	X	X	X	X	X	X	X	X	
OPTICAL TRANSMISSION	X	X	X	X	X	X	X	X	X	NTT
MULTI-MEDIA TRANSMISSION	X	X	X	X	X	X		X	X	
PC/VIDEO PROCESSOR	X	X	X	X	X	X	M500	X		Sumitomo Metal
MULTIMEDIA DATABASE	X	X	X	X	X	X				Sumitomo Metal
IMAGE PROCESSOR	X	X	X	X		X		X	PKOT	Victor
OPTICAL NEURAL NET	X			X		X			X	Tokyo U., ATR
FRAME MEMORY								X		
EDTV SYSTEMS	X									Sanyo, etc.
HDTV ENCODER/DECODER	X	X	X	X		X	X	X	X	Sanyo, Sharp, Victor, Canon

Source: Mark Eaton, "Japanese High Definition Systems: Research, Development, Deployment," MCC International Liaison Office, Austin, Texas, August 22, 1989.

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116. See, for example, Matsushita Electric, "Matsushita Electric Exhibition of Technology: Technical Report," [Osaka], 1989.
117. MITI, Agency of Industrial Science and Technology, *AIST 1989* (Tokyo: MITI, 1989), 7.
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119. MITI, "New Information Processing Technology," Tokyo, April 1990.

120. Wassily Leontief and Faye Duchin, "The Impacts of Automation on Employment, 1963-2000," Institute for Economic Analysis, New York University, New York (April 1984).
121. MITI, Industrial Structure Council, Information Industry Committee, Long-Term Outlook Subcommittee, "A Vision of the Information Industry in the Year 2000," (Tokyo, June 19, 1987), 85-111.
122. Paul Rosenstein-Rodan, "Problems of Industrialization of Eastern and South-Eastern Europe," *Economic Journal*, Vol. 55, 1943, 202-211.
123. Science and Technology Agency, op. cit.
124. Tatsuno, *Created in Japan*, 130, 136-137.
125. Science and Technology Agency, op. cit.
126. This significance has been recognized by the National Advisory Committee on Semiconductors, "A Strategic Industry at Risk," a report to the President and the Congress, November 1989, 7.
127. Tatsuno, *Created in Japan*, 138-141 and 145-148.
128. Davidson, "Japanese Telecommunications Industry," 2-3 to 2-5.
129. Rosenstein-Rodan, "Problems of Industrialization." Rosenstein-Rodan argued that significant linkages could be established between new industries that had very close input-output relationships during certain periods of economic development. Such circumstances create a powerful engine of economic growth and vitality, largely due to the broad interdependencies that are created in such a vital economy. The methods to identify such circumstances are not well defined. As a consequence, Rosenstein-Rodan's contribution has remained largely a conceptual device rather than an analytical tool. Perhaps the Japanese have figured out how to use his perceptions in their new policies.
130. Eaton, *Japanese HDS*.
131. Discussions between JTEC group and executives of Sony (Tokyo, May 29, 1989).



## **A MANAGEMENT ANALYSIS**

### **HIGH DEFINITION PRODUCTS AND SYSTEMS: THE STRATEGY OF LEVERAGE**

Richard J. Elkus, Jr.

#### **INTRODUCTION**

"High definition" as a phrase describes new products or systems whose value resides in their ability to process greatly increased amounts of audio and video information. Processing of information is fundamental to the infrastructure of electronics, telecommunications, and media markets. Therefore, to determine the impact of high definition systems on the economy of a country, it is important to understand the breadth and depth of the supporting infrastructure in terms of the markets for electronics, telecommunications, and media.

#### **BACKGROUND**

The purpose of this panel was to study the technological developments in Japan pertaining to high definition systems. As chairman of this panel, it is my hope that this study will give some insight into the strategic concepts pervasive within the Japanese industrial system that are different from those practiced within the United States. I was able to have discussions with several top Japanese business and government leaders, during which these executives clearly pointed to what they felt were substantive differences between strategic planning in Japan and in the United States. As the general concepts embodied in Japanese efforts to develop an infrastructure supportive of high definition systems

unfolded, it became apparent that these concepts were also fundamental to the development of the Japanese industrial complex as a whole and may give an insight into the change in the balance of economic, industrial, and technical power between the United States and Japan. The following four points were made at various times and in various ways during my meetings in Japan:

1. The technological development of high definition systems is essentially evolutionary in concept, design, and manufacture, even though the potential results of these developments in terms of products, markets, and investment needs might well appear to be revolutionary to outside observers. The implications of this statement are vast. Revolutionary concepts are often very difficult to understand and sell, take a long time to develop, and are very expensive to implement; they therefore tend to destabilize markets, often to the disadvantage of the pioneer. Evolutionary products, on the other hand, tend to make use of existing infrastructure which reduces development costs and are reasonably well understood by both producer and consumer. They, therefore, cause less market turmoil and tend to benefit the developer to the disadvantage of the competition.
2. Japanese efforts to develop high definition systems are part of a fundamental economic strategy that assumes products and markets will ultimately become interrelated and interdependent. That strategy is of tremendous importance considering the significant level of resources required for the development of high definition systems.
3. To support that competitive strategy, the leadership in Japan believes that a coordinated effort between all sectors of Japanese society is essential to the ultimate success of the base strategy. Thus, the Ministry of International Trade and Industry has as a primary role the job of ensuring that key sectors of Japanese industry talk to each other, and, where required, it will coordinate efforts.
4. Japanese political and business leaders feel that any loss in their position in the infrastructure of strategic end-use products and markets threatens their position of economic leadership. The Japanese premise is that the base strategy is fundamental to the success of the entire domestic economy and with that success, national self-determination and international leadership.

Japanese planning for the development of high definition systems appears to be near the core of Japanese strategic economic thinking.

Two other basic points were underscored in my discussions with key business and government representatives in Japan:

1. Products and markets become more and more interrelated during the course of development. The interrelationship of strategic products and markets creates an infrastructure that becomes very difficult to penetrate by competitors who lack positions of strength within that infrastructure. The power of an integrated infrastructure of end-use products and markets will begin to dominate technological development, intellectual property rights, component development, and the educational system itself--not the other way around.
2. The United States operates on the theory of opportunity cost. If you can make more money elsewhere, do it. But walking away from the development of end-use products and markets as a strategy literally forces the competition into a position of unparalleled economic strength. This is particularly true if that competitor understands the implications of the power of an infrastructure of interrelated end-use products and markets. Such is the position today between the U.S. and Japan.

Let us consider the above mentioned points against the following background. During the 1940s and 1950s, three United States companies created industries that became the foundation for many of the strategic world markets of today: RCA was instrumental in the development of television; Shockley Transistor Company spawned the semiconductor industry; Ampex Corporation developed the field of magnetic recording (Ref. 6.1). Today, television, telecommunications, computers, consumer electronics, and mass media have their roots in the contributions of these three companies.

As of 1970, America was virtually self sufficient as a nation. It encompassed the world's biggest market, produced more products, and had a larger trade surplus than any nation on earth.

Today only one U.S.-owned company produces television sets. The television market is dominated by Japan and Europe. Today the United States is virtually a nonparticipant in the market for audio and video recording. Today the United States is no longer the largest producer or clear technological leader in semiconductor design and manufacture. The United States' surplus balance of trade in computers is less than half of what it was in 1981. Moreover, America has a negative balance of trade with Japan in computers and related products. Loss of market positions in these strategic areas has begun to restrict America's control of its economic and political destiny.

These circumstances are summarized by the U.S. Department of Commerce International Trade Administration as it assessed the competitive status of the U.S. electronics sector from materials to systems:

The U.S. electronics sector has been historically and remains today the overall leader in the world by many measures. In terms of output, employment, innovation, and technology base, the United States is number one. However, in terms of the growth of these measures and others, such as exports, Japan and Korea are quickly reducing the U.S. advantage. In fact, if current relative growth rates continue, the Japanese will be the world's leading electronics producer and trader by the early 1990s (Ref. 6.2).

The Department of Commerce statement is consistent with comments made in a speech that I gave on July 9, 1988, based upon data from Cahners and Dataquest:

Electronics is now the largest durable goods manufacturing industry in the United States and is growing three times faster than other manufacturing.

The worldwide electronics market has become a mammoth business with a compounded growth rate approaching 9%. However, the projected growth rate for the electronics market in Japan is expected to be 40% greater than that of the United States.

Finally, in a chart entitled "U.S. Report Card: Trends," the Technology Administration of the U.S. Department of Commerce in its spring 1990 report on twelve emerging technologies noted that in comparison with Japan, the U.S. was:

Losing badly in advanced materials, biotechnology, digital imaging technology and supercomputers;

Losing in advanced semiconductor devices, high-density data storage, high-performance computing, medical devices and diagnostics, optoelectronics, and sensor technology;

Holding in artificial intelligence, flexible computer-integrated manufacturing, and gaining in none (Ref. 6.3).

The impact of the strategic development of an infrastructure of end-use products and markets on the financial prowess of Japan has been dramatic.

At the end of the World War II, Japan was a defeated nation. Under the aegis of General MacArthur's reconstruction plan, the *Zaibatsu* (major groups of interrelated companies) were systematically disassembled. Food was in very short supply and very expensive. Living conditions were difficult at best. Industrial output was basically at a standstill. Much of the country had been razed by the ravages of war.

The United States on the other hand came out of the war virtually intact. Economically and militarily, it was the strongest nation in the world. Its military might and economic prowess had reached heights greater than any nation had achieved in history. For many years after the war, much of the world was to depend upon the United States for financial support, food, and military protection. Japan was no exception. But things are different today.

Forty-five years after the end of World War II, the change in economic position between the United States and Japan has been staggering. In 1989, R. Taggart Murphy wrote:

Japan today sits on the largest cache of wealth ever assembled. It has the power to move markets anywhere in the world. Consider that: The Tokyo Stock Exchange has now surpassed New York to become the world's largest on the basis of market capitalization. Osaka has bumped London to fourth place. Of the world's ten largest banks, nine are Japanese. If deposit size is the unit of measurement, no U.S. bank makes it into the top 25. Japanese investors' appetite is the key determinant of the price of U.S. Treasury bonds. Japanese and Japanese-owned banks now supply more than 20% of all credit in the state of California. The market value of Japan, as measured by an extrapolation of real estate prices, exceeds that of the United States. The market value of the Imperial Palace grounds in central Tokyo is said to exceed that of a number of entire U.S. states (Ref. 6.4).

And, as David Hale noted, "Japan's top 13 banks are worth \$470 billion. America's top 50 are worth \$110 billion." (Ref. 6.5)

By the end of 1989, the capitalized market value of Nippon Telephone and Telegraph Corporation (NTT) was greater than the total capitalized value of all the stocks on the West German Stock Exchange. According to Albert J. Alletzhauser, author of *The House of Nomura*, one company, Nomura Securities, has grown to such an extent that "on some days Nomura's share of New York Stock Exchange volume has exceeded 5% and Nomura Securities has taken up as much as one quarter of newly issued United States Treasury Bonds."

On October 19, 1987, the New York Stock Exchange experienced a major crash that affected the entire financial world. The New York Stock Market dropped 508 points, or 23%. The world wondered if it could withstand such a financial blow and survive intact. On October 20, a member of the Ministry of Finance, Takashi Matsukata, indicated to the four major securities firms in Japan that they should act in concert to stem the pending collapse. The purchasing power of these firms began to reverse the tide of sellers, first in Tokyo and then in the rest of the world. The drop on the Tokyo Stock Exchange was held to 15%. By Wednesday, October 21, a full-fledged rally on the Tokyo Stock Exchange had ensued and continued through 1989 (Ref. 6.6).

In summary, the infrastructure of end-use products and markets developed within the Japanese economy appear to be increasing Japan's technological base at a faster pace than that being achieved within the United States. In addition, improving strength in end-use products and markets appears to be having a very favorable effect on the overall economy of Japan. Virtually all of the technologies, products and markets mentioned above will be augmented by, and in turn contribute to, the growth of high definition systems. Therefore, it is important to try to understand why there has been such a change in economic and industrial power between the United States and Japan in such a short time. The answer, in part, according to those interviewed can be found in the strategy implicit in the development of high definition systems.

## **JAPANESE ECONOMIC STRATEGY**

The following comments are based upon my experience in dealing with major corporate, business, and government leaders in Japan over the past twenty-two years, as well as my meetings in Japan as a part of this study. This experience included circumstances occurring between 1968 and 1972 that are now directly related to the current developments in high definition systems, including preparation of the product plan approved by the president and board of directors of Ampex Corporation for the initial development of the VCR, and management of the program to design and develop America's first entry into the world of the VCR (Ref. 6.7).

To the Japanese businessman, strategy is everything. Every person, every business, every industry must have a goal and a strategy to achieve it. Since resources are usually scarce, the successful Japanese plan includes the concept of leverage. Therefore, some markets are given a high priority and are considered more strategic than others. By targeting strategic markets, an infrastructure can be built which insures a solid basis for economic expansion. The leverage, however, is not based simply on the importance of one market over another, but on the assumption that over time and with development,

strategic markets will become interrelated and interdependent, with the whole becoming substantially larger than the sum of its parts.

### **Interrelatedness of End-Use Markets**

In the United States we tend to approach products, markets, and businesses as separate enterprises, like independent circles, with little emphasis on and few mechanisms for coordinating overall strategy and direction. These separate enterprises are often treated as profit centers. If the profit isn't adequate, the enterprise is often reorganized or disbanded in favor of a more profitable situation.

The Japanese, on the other hand, regard products, markets, and businesses as interrelated and interdependent enterprises, like links in a chain. They therefore feel that the coordination of strategy and direction is essential. This is a point fundamental to the strategy of product and market development in Japan. It is based on the concept that in pushing the development of a product or market to its logical extreme, it becomes related to other products and markets. Thus in Japan, rather than reject a product or market on the basis of profit potential, business strategy assumes that every product becomes the basis for another, every technology becomes the stepping stone for the next, and the resulting efficiencies of scale are enormous.

There are numerous areas in which one can see this principle at work. Following are several examples:

*Products.* There are obvious relationships between the optical systems of a video camera and a 35-mm camera. Similarities also exist in the electronic packaging and circuit design of VCR camcorders, 35-mm cameras, portable audio recorders, portable CD players, and television sets. The newly introduced digital audio tape recorder is a derivation of the VCR.

*Markets.* The development of the VCR created the market for prerecorded tape, a market now larger than movies for theater viewing. Similarly, the market for prerecorded tape directly influences the potential success of a video or audio recording format (for example, Beta versus VHS).

*Component Technologies.* The development of a major position in a strategic end-use market (for example, the market for VCRs) provides a primary source of demand for key components and technologies related to the development of these markets. The VCR has become a huge source of demand for semiconductors. In 1987, the VCR alone represented nearly 5 percent of worldwide semiconductor demand, and almost 12 percent of semiconductor production in Japan.

The semiconductor device provides the basic computing power and information storage capacity for most modern electronic products; as such, it is probably the single most strategic electronic component. Japan has, therefore, felt it essential to develop and maintain a large presence in the semiconductor industry, including participation in materials, equipment, and devices--not, however, through random investments. The development of the semiconductor industry is driven principally from demands and funds generated by related end-use markets for products such as that of VCRs, audio recorders, video cameras, 35-mm cameras, television sets, fax machines, computer products, and automobiles (all markets in which the Japanese have major positions). The prevailing philosophy of Japanese industry is that significant positions in strategic interrelated end-use markets, such as those mentioned above, provide an equally significant position in the semiconductor industry. Conversely, a significant position in the semiconductor industry will lead to domination of innumerable end-use markets not necessarily limited to the field of electronics.

### **Systems for the Future**

Matsushita Electric Corporation produced a book in English and Japanese entitled *Human Electronics - Matsushita Electric Exhibition of Technology - Technical Report*. This book outlines systems under development for future sale and use. The book, presented to me by Matsushita in June of 1989, includes the following sections:

1. Key Technologies for AV & CC
  - a. Displays
  - b. Semiconductors
  - c. Computers
  - d. Communication Systems
2. AC & CC for Living and Society
  - a. Home HDTV Systems
  - b. Home AVCC Systems
  - c. Information and Communication Systems for Automobile
  - d. Learning Systems
  - e. Office Systems
  - f. High Definition TV Studio
  - g. AV Studio
  - h. High Definition Video Theater
  - i. Home Auditorium
  - j. Digital Audio Car
3. Consumer Electronics Technologies
  - a. Video and Audio

- b. Housekeeping and Cooking
  - c. Air Conditioning
- 4. Fundamental Technologies
    - a. Lighting
    - b. New Materials
    - c. Sensors
    - d. Memories
    - e. Electronic Components
    - f. Batteries
    - g. Electronic Components in Automotive Applications
  - 5. Production Engineering Technologies
  - 6. Plant Biotechnology

The breadth of the development programs represented in this book is indicative of how one firm in Japan (Matsushita) looks at the interrelated aspects of various products and market areas. The following pages include an overview of two sections: Information and Communication Systems for the Automobile, and the High Definition TV Studio. The purpose of these exhibits is to illustrate the following points:

- 1. From the Japanese standpoint, products and markets become interrelated as they are developed. For example it is contemplated that the communications system in the automobile will be used to control electronic products in the home, including garage doors, microwave ovens, air conditioning and alarm systems, as well as fax machines and computers.
- 2. High definition television is only one aspect of the market for high definition systems. In reality, high definition systems, in time, will affect most products and markets as the requirement for and ability to process tremendous amounts of information increases.

Accompanying the two sections is a copy of an ad that appeared in several magazines, including a special issue of *Fortune* magazine in the fall of 1989. This ad by Matsushita Corporation is derived from the section on "Information and Communication Systems for the Automobile" included in its technical report as noted above.

The reason for its inclusion in this report is to add clarity to the concept of inter-relationship between products and markets espoused by the Japanese not only within management of their development programs, but in everyday literature as a part of their sales and marketing efforts.

松下電器のめざすものは、情報化時代に対応する安全・快適なカーライフです。それは、インテリジェント化され、さらにヒューマンな、もっとコミュニケーションを大切にした、ビジュアルコミュニケーションカーへの対応です。ここでは、AV & CC技術を駆使した、ナビゲーションや音声認識ハンズフリー電話・テレコントロール、さらにはファクシミリでそれぞれ、社会、家庭、オフィスと有機的につながるとともに、テレビ・ビデオデッキも含めた車載用情報システムとして、これからの新しいカーライフをご紹介します。

Agreeable automobile travel fully in tune with the coming information society age is what Matsushita aspires to offer the driving public; and this can be achieved by merging safe, practical visual communication systems within the automobile.

Displayed here are examples of information systems for use in your car now and in the future, which include; a navigation system, a voice command dialer and acoustic echo canceller for hands-free mobile telephone and tele-controller, a facsimile machine and video deck—all of which make full use of existing AV & CC technologies.

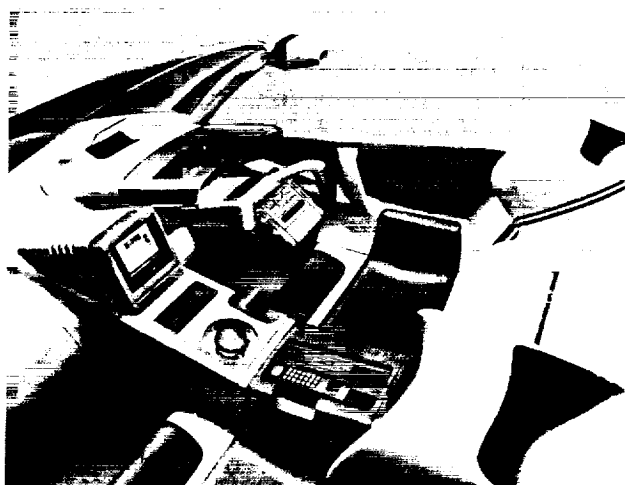


Figure 6.1. Information and Communications Systems for Automobiles



### システムの特長

#### ■ 社会システムに対応したナビゲーション

現在位置と目的地を入力すると、ディスプレイ上の道路地図に最短経路が示されます。また、リアルタイムで入ってくる交通情報に基づいて、迂回路の誘導も表示されますので、特に年々、交通の過密化が進む都市部においては、効率的なドライブを実現します。

#### ■ CCDカメラによる車周囲の確認

超小型CCDカメラにより、車両前方左右と後方の左右の状況をとらえ、モニタ画像で確認できるので、安全・快適なドライブを実現します。

#### ■ オフィス・家庭とつながる情報・通信機器

自動車電話、車載用ファクシミリにより、オフィスと情報のやり取りをし、本格的なカーオフィスを実現します。また、車内から電話によるテレコントロールで家庭内の機器操作を可能にしています。さらに、自動車電話は、音声認識によるダイヤルとハンズフリー通話が可能なので、ステアリングから手を離すことなく安全なドライブを実現できます。

#### ■ ヘッドアップディスプレイ

スピードメータ、ウィンカ、道路地図などの情報をフロントガラス面に、運転に支障がないように虚像画面として表示し、効率的で安全な運転操作を可能にします。

### Features of the system

1. The best navigable route instructions, derived by inputting present location and intended destination. Traffic congestion and current road construction information offers re-routing possibilities as a portion of the communication.
2. Constant surveying of the immediate surroundings of the car performed by a CCD camera to confirm safety conditions.
3. Information and communication equipment including telephone, facsimile, and remote-controller which connects the car to office or home.
4. Windshield information display aiding the driver to keep eyes on the road for safety.

Figure 6.2. Information and Communication Systems for Automobiles: Features of the System

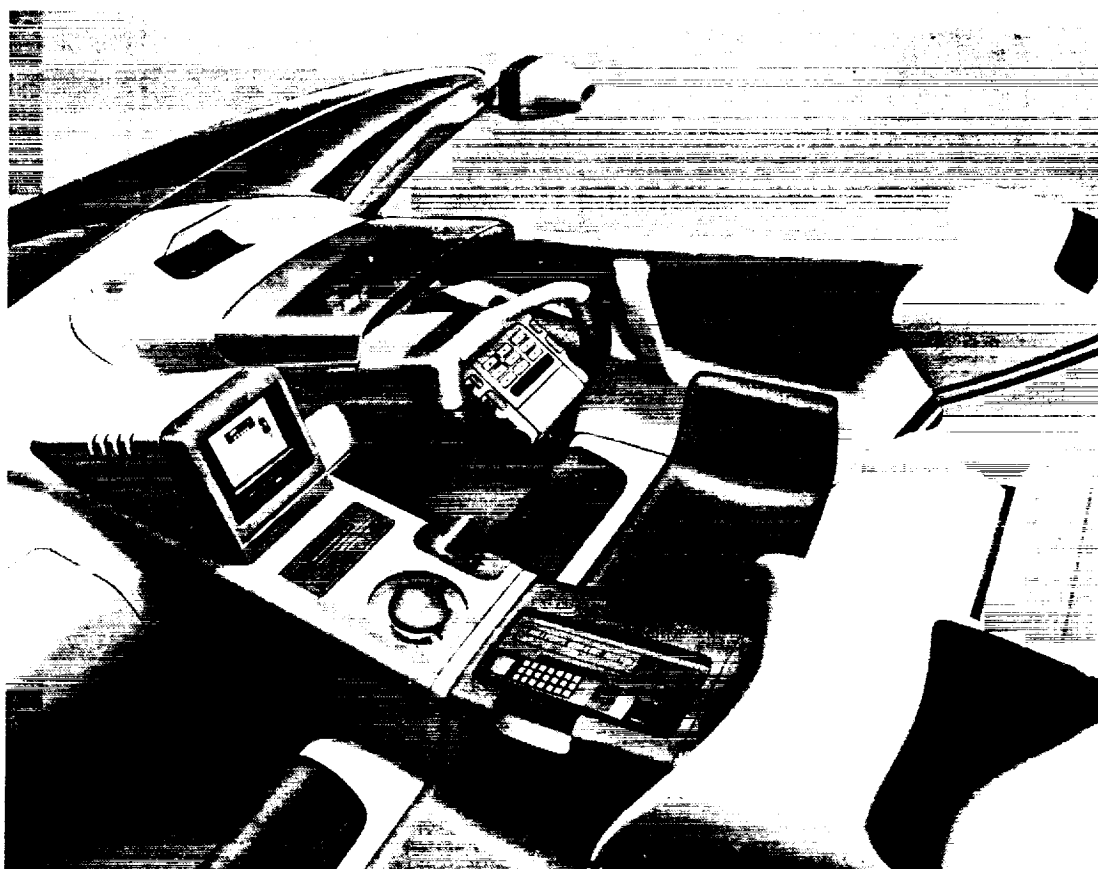


Figure 6.3. Human Electronics--Technology for the Benefit of Mankind

## Put eyes in the back of your head. A navigation system in front of your nose. A telephone and fax in the middle of everything.

A map pinpointing traffic jams flashes across your car's video monitor. Another monitor shows you right, left and rear views. All this as well as a voice command phone and mobile fax are but a few of the advanced electronic systems that Matsushita Electric is working on today, to make driving safer, easier and more convenient tomorrow.

You're late for work, heading toward a traffic jam and there's nothing you can do about it. In the future, this may not be a problem because of the advanced automotive electronic systems under development at Matsushita.

### VISUAL INFORMATION SYSTEM

Should you take the highway or the boulevard? Or maybe the back roads? Someday, your car's navigation system will take care of all that. A navigation map will show you traffic jams on a sophisticated video screen and show you exactly where you are. So you can choose the fastest, most efficient alternate route.

Today, you glance down to see the speedometer, up for the rear view mirror, left and right for side views. Matsushita is working on a system that will replace side and rear view mirrors

with video cameras and monitors. And a unique Head-Up Display located in your line of sight will show you speed, fluid levels and a map. So you should never have to take your eyes off the road.

### THE COMMUNICATIONS CENTER

To make your time on the road more productive, Matsushita is developing a mobile fax that will connect your car to your office, home and beyond. A voice command mobile phone lets you call anyone by simply saying his name out loud. In any pre-programmed language. And linked with Matsushita's home automation technology, the sound of your voice will lock or unlock the front door of your home, turn on the microwave oven or turn on your air conditioner. All from your car.

### HUMAN ELECTRONICS

Advanced electronic systems like these are an example of how Matsushita Electric is devoted to the concept of Human Electronics. Matsushita's objective is to research, develop and market products that make life richer, safer and more comfortable. These products are sold under the brand names Panasonic, Technics, Quasar and National. In 1988, Matsushita's consolidated sales volume surpassed \$41.7 billion. All a direct result of a single-minded philosophy: Don't create new technology for technology's sake, but for man's sake.

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**MATSUSHITA ELECTRIC**  
PANASONIC TECHNICS QUASAR NATIONAL

Figure 6.4. "Put Eyes in the Back of Your Head"

将来は3兆円市場に成長するといわれているハイビジョン。最大の市場はテレビ放送関係、特に家庭用の受像機になることは確実ですが、デジタル化による多彩な画像処理と色調の忠実な再現性によって、映画、印刷、出版、医療など、テレビの領域を超える映像分野や、精緻な芸術性が要求される分野での利用にも大きな可能性を持っています。

このコーナーでは、ハイビジョン放送用のスタジオシステムおよび幅広い分野での活用が考えられるさまざまなハイビジョン関連機器をご紹介します。



It has been said that High Definition TV would create a 25 billion dollar industry in the future, dominated primarily by the TV broadcasting market principally utilizing home TV receiver units. However, benefiting from the versatility of picture processing technology and by virtue of its capability for excellent color reproduction, High Definition TV has endless possibilities.

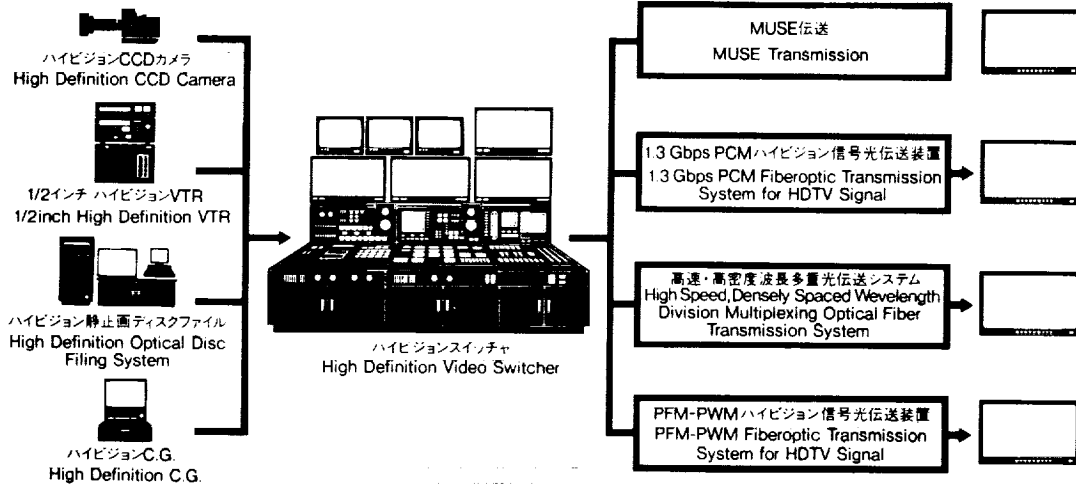
The vast range of possibilities for High Definition TV include, in addition to video; movies, printing, publishing, medical treatment, and a host of other areas where a high degree of artistic skill is required.

Presented in this corner is an example of a High Definition broadcasting studio system, as well as samples of High Definition related equipment to be used in some of its possible fields of application.

Figure 6.5. High Definition TV Studio

## ハイビジョンスタジオシステム解説

### High Definition TV Studio Systems



#### システムの特長

- ハイビジョンCCDカメラ  
130万画素FIT-CCDを使用した3板カラーカメラ。高品質画像が得られます。
- 1/2インチ ハイビジョンVTR  
M-II VTRの技術を基本にした高性能VTR。当会場の家庭用HDTVシステム、ディスプレイの信号送出にも使われています。
- ハイビジョン静止画ディスクファイル  
1画面4秒以内の高速画像表示が可能。スキャナによる画像入力や、プリンタでハードコピーも行なえます。
- ハイビジョンC.G.  
高品位の文字・図形をリアルタイムに送出するハイビジョン用Character and Graphic Generation System。
- ハイビジョンスイッチャー  
ハイビジョンスタジオの中核システムとして、映像の加工に大きな効果を発揮します。

#### Features of the System

1. High Definition CCD Camera  
A color camera that employs three 1.3 million pixel FIT-CCDs.
2. 1/2 inch High Definition VTR  
A high performance VTR that was developed based upon the M-II format VTR technology employed for transmitting home HDTV systems and display signals.
3. High Definition Optical Disc Filing System  
This system makes practicable high speed picture displays at the rate of one still frame every four seconds, use of a scanner for picture filing, and production of hardcopy by utilizing the printer function.
4. High Definition Character and Graphic Generation (C.G.) System  
Real-time transmission of High Definition characters and figures using the character and graphic generation system is another example of the versatility of this High Definition studio system.
5. High Definition Video Switcher  
At the heart of High Definition TV studio systems is the High Definition Video Switcher performing the core function of processing the video signals received and making them compatible with the system.

Figure 6.6. High Definition TV Studio Systems: Features of the System

### **Strategic Nature of Electronics Markets**

The Japanese feel that a strong participation in strategic interrelated end-use markets will have as important an influence on technology in general as it has on the technology of semiconductor products in particular. In other words, their view is that domination of strategic interrelated end-use markets will lead to the domination of the use and direction of technology, not the other way around. This relationship is borne out by the Japanese experience. The Japanese now dominate or have a significant position in the following markets:

1. The videotape recorder market, including professional, commercial, and consumer applications
2. The video camera market, including professional, commercial, and consumer applications
3. The 35-mm camera market
4. The consumer television receiver and monitor markets
5. The consumer and commercial audio recorder markets
6. The compact disk playback system market
7. The video disk market
8. High speed digital fiber transmission equipment
9. The optical disk market
10. The market for digital watches and solar-powered calculators, radios and television sets
11. The market for personal computers, workstations, and lap-top computers

Based upon its position in the above markets, Japan has gained a preeminent position in the development and production of optical systems and devices, displays, semiconductors, semiconductor equipment, semiconductor materials, and various components of mass memory systems. Japan's overall market position has improved dramatically as it pushed the development of specific end-use products to their logical extremes.

### **Cost Efficiency of Retaining Markets**

At the same time, the cost of competitive entry (or reentry) into strategic markets (such as the VCR market) has escalated dramatically. For example, the development of a semiconductor device that cost a few million dollars a few years ago, may cost in excess of a billion dollars today. Similarly, the cost of a VCR facility 20 years ago would have been less than \$10 million, whereas today that facility might cost as much as \$600 million. Other costs also rise, largely due to the interrelationships that exist today between technologies, components, products, and markets. While participants in the video recording market 20 years ago could concentrate almost exclusively on the technology of putting pictures on tape, they must now possess high levels of sophistication in

a host of interdependent products and fields: digital signal processing; displays, cameras and optics; semiconductors; computers; high-volume, fully-automated manufacturing; and mass marketing and distribution. Moreover, the trend is now towards convergence between the VCR and media industries, adding yet another dimension to start-up costs.

In an article entitled "Losing Control (Auto Industry Is Sliding Relentlessly Into Japanese Hands)," Paul Ingrassia stated:

By moving from exporting cars to the U.S. to building them in the American heartland, the Japanese are steadily taking over the American car industry. It is one of history's great transfers of industrial wealth and power (Ref. 6.8).

A similar article appeared in *The Economist* on April 14, 1990. This article, entitled "Detroit Under Siege" noted that:

As recently as 1978 the Big Three made 82% of the cars sold in their all-important American market. Today they have just 67% of American sales, a slide which most market analysts expect to accelerate over the next four years (Ref. 6.9).

Why is this happening? These articles talk about Japanese knowledge in producing efficient small engines. They discuss the inefficiency of the large automobile corporations in the United States. They talk about the large investment in research and development by Japanese corporations in the automobile industry. But, something else is also happening.

In the past, approximately 5 percent of the cost of an automobile was based upon electronic components and systems. Many technical experts now project that 30 to 35 percent of an automobile will be comprised of electronic components and systems by the mid 1990s. As is suggested in the commentary by Matsushita (Ref. 6.8) under the heading "Information and Communication Systems for Automobile," the infrastructure for end-use products and markets in the electronics sector of Japan is becoming a significant part of the infrastructure of the automotive industry. Technical advances in radios, sound systems, mobile telephones, fax machines, satellite communication systems, displays, video recorders, cameras, and semiconductors are rapidly becoming fundamental to the automobile of the future. Over time, U.S. companies have found many of these product areas less profitable than others, and using the theory of opportunity cost have shifted their resources elsewhere. Today these products and markets are becoming increasingly dominated by the Japanese and manufacturers in other countries. Hence, American automobile firms often find it necessary to buy electronic components and systems from suppliers

strategically more closely associated to their competition than to themselves. Lack of strong strategic relationships with appropriate electronic component and equipment suppliers may significantly reduce the overall competitiveness of U.S. car manufacturers by limiting their design and performance specifications, let alone cost.

As products and markets evolve, the technological improvements increase the sophistication of those products and markets in startling ways. In that regard, at the conclusion of the trip to Japan by the panel on high definition systems in June of 1989, Mr. Lawrence E. Tarnas, Jr., a member of the panel and then president of the Society for Information Displays, said that in his opinion the sophistication of display and electronics packaging techniques incorporated in consumer products on the store shelves in Tokyo was in many cases equal to or better than the display and electronics packaging techniques produced by the Department of Defense. In a way, Mr. Shintaro Ishihara, in his book *The Japan That Can Say "No"*, alluded to these differences by commenting on the Soviet and U.S. dependency on the superiority of Japanese technology for certain strategic weapon systems.

Thus, while firms in the United States may be willing to drop a product or market on the basis of "opportunity cost" and reinvest in a more lucrative enterprise, Japanese firms usually will not. Because of their concept of relationships between products and markets, the Japanese feel that to abandon a product or market means the potential loss of other related products and markets and, therefore, the loss of valuable infrastructure. This infrastructure of strategically related end-use products and markets can provide the basis for future economic growth and development. The result of the Japanese economic strategy to target and dominate certain strategic interrelated end-use markets is to significantly reduce the threat from any competitor attempting to enter a market or gain market share on the basis of a technological breakthrough or some special expertise.

### **Long-Range Plan for High Definition Systems**

This is where high definition systems become important. Defined in its broadest terms, high definition technology encompasses the production, transmission, recording, processing, and display of greatly increased amounts of audio-visual information. The market for high definition systems can, therefore, help push the markets for electronics products, telecommunication services, and software (including mass media) to their logical extremes. The Japanese feel that in time, perhaps by the year 2000, the requirements and possibilities created by improving the technology of rapidly processing huge amounts of audio-visual information will force a confluence of these three end-use markets into a single information systems market. They expect that the information systems market

will, within the next ten years, represent 33 percent of all capital investment, 44 percent of all new jobs and 22 percent of all economic growth. The Japanese further anticipate that the information systems market will evolve into an information-based economy, which in turn will help bring about an advanced social order.

In a 1989 brochure entitled *Advanced Television, The Promise And The Challenge*, the Japanese Ministry of Posts and Telecommunications stated:

We live in a society of transition. A society which is abandoning its past obsession with materials and energy to make room for a new allegiance to information and knowledge. As the advanced information society resulting from this change in emphasis matures, the uses and services connected with the products and material objects will gain precedence over their mere possession. In the process, the distortions arising from the concentration of population and industry in the large cities and our industrial society will be resolved. Tomorrow's city dwellers will share access through the media to information of all types. National and local governments and private enterprise must all work together to create this new society aimed at enabling people to lead richer lives both materially and spiritually.

Thus far, advances in information processing, centering on computer and networking technologies, have been mainly in the domain of sound and symbols (data and alpha-numeric characters). From now on, however, these will be joined by advances in the visual media as the latter gradually come to form the core of social activity (Ref. 6.10).

## **EFFECTIVENESS OF THE JAPANESE STRATEGY: A CASE STUDY**

### **Ampex and Sony--History and Comparison**

A significant portion of the transition referred to in MPT's brochure will occur because of products and technologies initially developed, produced, and marketed by two companies--Ampex Corporation of the United States and Sony Corporation of Japan. Since the late 1950s, the relationship between Ampex and Sony has been one of both cooperation and competition. Although Sony's early growth was tied to its development of the "pocket radio," it was Ampex's pursuit of magnetic recording, and in particular, its development of the videotape recorder, that became the cornerstone of growth for both firms.

At the time of its introduction in 1956, few could perceive the change that Ampex's development of the videotape recorder would bring to mankind.

Ampex, Sony, and other companies have derived innumerable new products and technologies from the early VTR technologies. In combination, these technologies have affected lifestyles, communications, economics, and even politics throughout the world. Together, they now constitute much of the foundation for the development of high definition systems, the basis of what the Japanese today call the "New Media." Together they are pushing society into an "information age." And despite the fact that the initial development of these critical products and technologies occurred primarily in the United States, today they are dominated by electronics companies in Japan. It thus seems worthwhile to review a bit of Ampex and Sony history.

In 1946, Sony Corporation of Japan commenced development of products in the commercial marketplace under the leadership of Masaru Ibuka and Akio Morita. In that same year, Ampex, a small U.S. corporation led by Alexander Pontiatoff, was reviewing the possibility of magnetic recording as demonstrated in the design of a German audio tape recorder. In its early years, Sony attempted to establish a position in the design, production, and marketing of transistor radios based on technology that was initially developed by Dr. William Shockley of Bell Labs. Ampex meanwhile had entered the commercial marketplace with the magnetic tape recorder. At first, Ampex's developments were strictly in the area of audio recording. However, in 1956, a technical group under the direction of Charles Ginsburg at Ampex completed the development of a device that was to change the course of history--the videotape recorder. With the first recorded reflections on the television screens at the convention of the National Association of Broadcasters in 1956, the world learned of the preeminence of Ampex technology.

As Ampex worked to improve its videotape recorder, it saw a need for solid state devices in place of vacuum tubes. At the same time, it wished to manufacture and market its recorders in Japan, and Japanese regulations required it to have a Japanese partner. Sony, under a license from Bell Labs for use of certain semiconductor technology, had developed a proficiency in electronics packaging techniques, and it appeared to be the logical partner for Ampex in both situations. As a result, in 1960, Ampex and Sony entered into a simple partnership that effectively traded Sony's understanding of electronic packaging technology for Ampex's license to manufacture videotape recorders in Japan.

But 1960 marked the first of several major fiscal crises for Ampex. With the financial reversal of 1960, Ampex received a new management team. The leader of that team, William Roberts, felt that the technological exchange with Sony would be detrimental to Ampex's long-term growth. As a result, Ampex broke off its technical exchange and manufacturing agreement with Sony, but

granted to Sony a license to build helical scan nonbroadcast videotape recorders.

By 1960, Sony and Ampex, both actively involved in the field of audio and video recording, had embarked on different strategic paths. Sony continued to maintain a philosophical commitment to push the development of a product to its logical extreme. This process began to demonstrate obvious interrelationships between its products and markets. As product specifications improved, their size and weight declined, and reliability increased, the line between consumer and commercial markets began to blur. Sony's sales expanded accordingly.

Ampex, on the other hand, tended to concentrate on a specific technological advantage in order to maintain a given market niche and related profit margins. Ampex's technology was obviously applicable to a broad range of products and markets. Yet, the implications of the interrelationship and interdependence of its products and markets was never clearly understood since there was no established strategy for pushing the development of those products and markets to their logical extreme. Consequently, Ampex was constantly faced with the decision whether to enter, remain, or leave a market simply on the basis of a competitive threat and its potential effect on near-term profits.

During 1960-1970 the market for video recording grew, but remained relatively small (approximately \$200 million and 16,000 units in 1970). The largest dollar portion of that market represented video recorder equipment utilizing a transverse scanning recording format for the broadcast industry. A smaller but growing portion was made up of videotape recorders and accessories for closed-circuit television based on a helical scan recording format and used principally for industrial and educational applications. The bulk of the unit volume of these closed-circuit systems were reel-to-reel recorders, produced by Japanese companies under license to Ampex. However, Ampex remained the predominant producer of videotape recording equipment, representing as much as 75 percent of the total market (in terms of dollars) (Refs. 6.11, 6.12). During that same decade, the market for audio recorders and 35-mm cameras grew quite rapidly. Due to their strategic planning and industrial electronic packaging expertise, the Japanese were becoming a major factor in both these markets.

Three events in 1970 set the stage for a fundamental change in parity between the industrial complexes of the United States and Japan:

1. Ampex introduced a product called Instavideo, the world's first entry into what was to become the VCR market. Through its joint venture partner, Toshiba, Ampex was participating with other Japanese firms in a

continuing series of discussions aimed at establishing a VCR recording standard.

2. By the end of 1970, significant disproportional growth in inventory and receivables investment began to severely constrain Ampex's cash position.
3. NHK, the National Broadcast Network in Japan, began a significant program for development of a direct broadcast system for high definition television (called MUSE).

By 1972, Ampex once again underwent a major reorganization for financial reasons, and as a result, it halted further investment in the Instavideo program. Ampex executives felt at that time that they didn't belong in consumer video markets; they wished to concentrate on the broadcast industry where margins and profit potential based on past performance were reasonably secure. At the same time, the market for broadcast and closed-circuit video recording was beginning to be affected by the introduction of new and improved helical scan video recording systems from Japan, including the Sony U-Matic cassette recorder. Although the size, weight, and cost of the U-Matic system precluded a mass market, it was an indication of things to come. Other systems that followed were Sony's Betamax VCR system in 1975, and the VHS VCR systems produced by Matsushita and a number of other Japanese companies (Ref. 6.13). Ironically, the introduction of the system by Sony was aided in part by Ampex engineers who had formerly been employed on the Instavideo program and were hired by Sony after the cancellation of Instavideo.

By 1985, the videotape recorder market, primarily due to VCR production, was worth \$15 billion. VCR production had reached a rate of 2.5 million units a month in Japan alone. In addition, helical scan technology had become the method of choice for video recording in the broadcast industry. With the VCR came the new, potentially more far-reaching market of prerecorded tape. For the first time, the media was able to bypass telecommunication services and reach the consumer directly through the mass distribution of prerecorded tapes. The market for prerecorded tapes in the United States eventually surpassed the total market for films in theaters. The world of audio/visual communications would never be the same again; perhaps more importantly, the development, manufacture, and marketing of consumer electronics products like the VCR were no longer dominated by the U.S. By 1985, Ampex sales amounted to less than 2 percent of the worldwide market for videotape recorders.

## Sony Today

The panel on high definition systems met with many Japanese companies involved in the production of high definition products; many of the products were impressive. The array of high definition systems produced by Sony were as advanced as any group of products we saw in Japan. Sony's Chairman, Mr. Akio Morita, and various other members of the management team made it clear that the videotape recorder was a fundamental part of the growth of Sony's business. This is particularly noteworthy when one begins to get an idea of Sony's comparative size and direction, as revealed in its 1988 annual report:

1. Total sales for fiscal year 1988, not including those of recently purchased CBS Records, amounted to approximately \$11.6 billion.
2. The \$2 billion CBS Records acquisition "... was financed by short-term loans, commercial paper issued in Japan, and internal funds. This short-term debt was refinanced in April, 1988, when we issued 20 million new shares of Common Stock and 92 billion (\$736 million) of 1.4% unsecured convertible yen bonds through public offerings in the Japanese market. These capital procurement activities raised a total of about 200 billion (\$1.6 billion) . . ."
3. Before the refinancing, Sony's debt to equity ratio was less than two to one.
4. Sony's reasons for purchasing CBS records were described in these terms: "As a subsidiary of Sony, CBS Records is expected to contribute significantly to the corporate growth, enhancing our audio/visual strategy by enabling us to jointly develop the hardware and software segments of the market." The purchase of CBS records by Sony probably also contributed to a change in receptiveness on the part of the U.S. recording industry to the importation of digital audio tape recorders from Japan. These products, based in part on the helical scan concept of the VCR, were considered a threat by the U.S. recording companies because of the potential for pirating vault-quality media available on compact disks. Sony produces digital audio tape recorders.
5. By 1988, Sony had become a major producer of computer workstations.
6. In 1989, Sony purchased Columbia Pictures for \$3.4 billion, and also Materials Research Corporation, a major manufacturer of sputtering equipment for the U.S. semiconductor industry.

7. By the year 1990, Sony's annual revenues were greater than 20 billion dollars.

In comparison, Ampex's 1988 sales were \$701 million. The largest single line item of income on Ampex's financial statement was that of royalty payments from Sony and other Japanese licensees of Ampex video technology. A significant proportion of Ampex's video recorder sales were Sony broadcast VCR systems repackaged under the Ampex label. By the end of 1988, Ampex, purchased on the basis of a leveraged buy-out, had a debt to equity ratio greater than 17 to one. Its research and development expense was less than the interest paid on its debt.

Sony has not been the only Japanese firm to take advantage of the growth of the market for VCRs and related products. Other Japanese companies involved in producing audio and video recorders have experienced similar growth during the past 20 years. The growth of these companies and the tremendous amount of capital used to finance that growth, is in large part the result of Japan's success in developing a whole series of interrelated end-use products and markets, commencing in part with the development of the videotape recorder and now aimed at integrating the markets for media, telecommunication services, and electronics through high definition systems.

### **The Strategy as Applied to High Definition Systems**

"High definition" is a phrase that defines and emphasizes the ability to record, process, distribute, and play back greatly increased amounts of audio/visual information. Thus the concept of high definition systems can be applied not only to television, but also to image processing, realtime two-way audio/visual communications, medical imaging and analysis, printing, and many other markets. While high definition systems may have been an outgrowth of television broadcasting and videotape recording, their growth depended as well upon a vast infrastructure of other interrelated products, including 35-mm cameras, video cameras, audio recorders, video recorders, television sets, laser and optical disk systems, computer products, fiber-optic transmission systems, solar-powered electronics, and satellite systems. In turn, these products have resulted from the mastery of the technologies of semiconductors (including equipment and materials), optics, various display systems, (commercial) lasers, electronic packaging, and other essential components. Also requisite to the success of high definition systems is participation in software (including mass media such as music videos and films) and firmware, which encompasses digital compression algorithms and digital signal processing.

In 1970, the U.S. was the major developer of electronic products and had established a significant infrastructure that included all of the above areas or

their precedent products and technologies. Today, with the exception of the media, certain computer products, and telecommunication services, the U.S. is heavily, and in some areas totally, dependent upon the rest of the world (significantly Japan) for a great part of this technological infrastructure. Is this important? Who cares, so long as a cheaper or more reliable product can be bought abroad?

The Japanese care a great deal. As a result of 40 years of planning and coordinated effort, the above mentioned infrastructure is not only virtually in place in Japan, it exists in relatively complete form in several companies, including Sony.

### **The Development of Multimedia**

One of the most fertile markets that will be advanced by high definition systems is that of multimedia. *Business Week* ran an article on October 9, 1989, entitled "It's a PC, It's a TV, It's Multimedia. Add a CD Here, a VCR There, and You May Have a Computer Revolution." *Business Week* defined multimedia in this way:

*Video.* Special microchips could make a multimedia encyclopedia show film clips of Martin Luther King Jr.'s famous speeches, as well as provide essays about his work.

*Audio.* Loudspeakers and an amplifier could let synthesized voices guide persons through a complex computer application, enhancing the usual visual aids

*Laserdisk.* Storing the equivalent of hundreds of floppy disks, the optical disk would be the means to distribute multimedia titles.

*Central Processor.* Key to it all are high-speed computer chips designed to process digitized video images for instant replay.

The article went on to say, "Now, the PC is receiving a major transfusion of video technology. That should lead to a dazzling new hybrid that can display sharp, moving color images on the same screen with spreadsheets and text. Add to that high-fidelity sound and some imaginative software, and the PC may become a "multimedia" tool that once again could change the way people work, learn, and play."

Unlike any single company in the United States today, Sony now has the complete infrastructure necessary to be a principal player in the market for high

definition multimedia systems, including its own media bank to insure appropriate integration of systems.

As the interrelated infrastructure of proprietary end-use products and markets has been of major importance to the development of Sony Corporation, it has been of equal importance to the development of the industrial infrastructure of Japan. As is the case with Sony, this infrastructure of end-use products and markets in the area of media, telecommunications, and electronics provides the basis for significant investments in high definition systems. Several large companies possessing much of this infrastructure have made major commitments of funds for development of high definition systems. These companies include Hitachi, Mitsubishi, Sharp, Toshiba, Matsushita, NEC, Nikon and others. Conversely, the development of high definition systems by these firms substantially increases the growth prospects of their supporting industrial infrastructure. As has been stated above, the resulting economies of scale can be decisive.

## CONCLUSION

In the information-oriented world of the future, Japanese leaders feel that any nation that does not have a proprietary position in, or reliable strategic access to, each of the market segments comprising electronics (including consumer electronics), the media (including software and mass media), and telecommunication services, will be at a significant competitive disadvantage to those that do. If they are right, the concept of withdrawing from the development of products and markets on the basis of opportunity cost is a risky strategy.

Several top Japanese executives indicated that the end-use market infrastructure in electronics, as it exists today in Japan, is superior to that of the United States, and moreover, that the interrelationships that bind this infrastructure together present a major obstacle to the possibility of competitive reentry, let alone catch-up.

Japanese corporate managers also feel that the infrastructure in electronic products now in place in their country will become one with that of media and telecommunication services, linked together by the ability to process massive amounts of audio/visual information. The unifying theme for this development is the concept of high definition systems.

Assuming that the combination of the markets for electronics, telecommunications, and media is the basis for entry into the information age, and recognizing that high definition systems are fundamental to the confluence

of these three market areas, the following conclusion should be considered: Any significant loss of infrastructure of proprietary end-use products and markets within the areas of electronics, telecommunications, and media may substantially reduce the growth potential of an economy dependent upon that infrastructure. The Japanese feel, and statistics tend to confirm, that the infrastructure represented by the markets for electronics, telecommunications, and media are of major significance to the economic and political development of the United States, Japan, and Europe.

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## **APPENDICES**

### **A PROFESSIONAL EXPERIENCE OF PANEL MEMBERS**

#### **Richard Elkus, Jr. (Chairman)**

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Mr. Elkus is presently (1983-Present) the Chairman and Chief Executive Officer of the Prometrix Corporation. In addition, since 1985 he has been the Director and Vice Chairman of the Board for Integrated Systems. Previously, (1959-1964 and 1968-1971) Mr. Elkus worked with the Ampex Corporation in several capacities including Assistant to the President and Manager of Educational and Industrial Products Division. Between 1974 and 1980 he was the Executive Vice President and General Manager of Geometrics, Inc. From 1980 to 1983, he was the Chairman of Pacific Measurements, Inc.

Mr. Elkus received his B.A. from Stanford University in 1957 and his MBA in 1959 from Dartmouth College, Tuck School of Business Administration.

#### **Dr. Robert Cohen**

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Dr. Cohen is currently (1987-Present) serving as Economic Advisor to New York State Director of Economic Development as well as being Senior Economist, New York Industrial Cooperation Council, and Deputy Director and Senior Economist to New York State Financial Services Advisory Commission.

Previously Dr. Cohen (1978-1979) was Senior Economist, Analytic Sciences Corporation, (1979-1982) Senior Research Scientist, New York University and Columbia University. From 1980 to 1984 he was an Associate Professor, City University of New York. In 1984 he became a Consultant, High Technology Economic Development Programs for the New York State Urban Development Corporation.

Dr. Cohen received his B.A. in 1965 from Swarthmore College. He was awarded his M.A. in 1978 and his Ph.D. in 1978 from New School for Social Research. Both degrees are in economics.

**Mr. Birney D. Dayton**

NVISION  
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Mr. Dayton is President and CEO of NVision, a company he founded in March 1989 with Guido Galli and William Amos. The company designs and manufactures High Definition Television and Audio production equipment. Prior to that (1986-1989), he was Vice President, General Manager of The Grass Valley Group, Inc., where he managed their thrust into the telecommunications market. In addition, Mr. Dayton has held positions of Project Manager, Staff Engineer, and Design Engineer in the development of a wide range of video products including routing switchers, production switchers, processing amplifiers, distribution amplifiers and sync generators. He developed the first fiber-optic video system used over the air (by ABC at the 1980 Olympics). Mr. Dayton received his BSEE degree from the University of Nevada, Reno. He holds eight patents and has authored numerous papers.

**Dr. David Messerschmitt**

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Dr. Messerschmitt is currently a Professor of Electrical Engineering and Computer Sciences at the University of California, Berkeley (1977 - Present).

His present research interests include digital signal processing, including applications to digital communication, video compression, and speech recognition. In addition since 1977, Professor Messerschmitt has served as Consultant to a number of organizations including TRW Vidar, Mountain View, California (participated in design of digital radio systems and performance evaluation of digital switching systems), IBM Research Laboratory, San Jose, CA. (research on application of communications signal processing to magnetic disk systems) and American Satellite, Rockville, MD (design of digital speech interpolation satellite system, planning for future ISDN networks. From 1968 to 1974 Dr. Messerschmitt was a Member of the Technical Staff and from 1974 to 1977 Supervisor at Bell Laboratories, Holmdel, N.J. While with Bell Laboratories Dr. Messerschmitt did research, systems engineering, and exploratory development in all areas of digital communications, including transmission lines, multiplexes, channel banks, and waveform encoding using digital processing techniques. He also supervised construction of exploratory digital transmission terminals, including digital speech interpolation and adaptive differential pulse-code modulation. In 1983 he was a co-founder, in 1983, of Teknekron Communication Systems located in Berkeley, California.

Dr. Messerschmitt was awarded his B.S. degree from the University of Colorado and his M.S. and Ph.D. from the University of Michigan. He holds numerous honors and awards including the Ira Kay Memorial Award for the Best Paper at the 22nd annual Simulation Conference, 1989 and the 1988 Prize Paper Award, IEEE Trans. on Acoustics, Speech, and Signal Processing.

#### **Dr. William F. Schreiber**

Electrical Engineering Department  
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Dr. Schreiber attended the New York City public schools and Columbia University where he received the B.S. and M.S. in electrical engineering. In 1953, he received the Ph.D. in applied physics at Harvard University, where he was a Gordon McKay and Charles Coffin fellow. He worked at Sylvania from 1947 to 1949 and at Technicolor Corporation in Hollywood, California from 1953 to 1959. Since then he has been a faculty member at MIT, retiring in 1990 as professor of electrical engineering and Director of the Advanced Television Research Program. He was visiting professor of electrical engineering at The Indian Institute of Technology, Kanpur, India, in 1964-1966, and at INRS-Telecommunications, Montreal, Quebec, 1981-1982.

Since 1948, Dr. Schreiber's major professional interest has been image processing. He has worked in graphic arts, including color processing and laser scanner design, in facsimile, and in television. This work has included theory and extensive practical applications. He is a Fellow of the IEEE, an Honors Award recipient of the Technical Association of the Graphic Arts, and has three times received the best-paper award of the SMPTE Journal. In October 1990, he will receive the David Sarnoff Gold Medal of the Society of Motion Picture and Television Engineers.

**Mr. Lawrence E. Tannas, Jr.**

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Consultant  
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Mr. Lawrence Tannas, Jr., President of Tannas Electronics, is an internationally-recognized consultant and lecturer on electronic information displays--consulting on technology, market studies, designs and design reviews, technology tours of Asia, etc. He received his BSEE (1959) and MSEE (1960) degrees from UCLA. Prior to beginning his consulting business in 1983, he worked as individual contributor and engineering manager at GE Research Laboratories, Honeywell, Martin Marietta, Rockwell International, and Aerojet ElectroSystems. While at Honeywell, he invented the backup reentry guidance display for the Apollo Reentry Vehicle; while at Rockwell International, he developed the engineering prototype LC display for the world's first full-scale LC display production; and while at Aerojet ElectroSystems, he perfected a manufacturing process for EL displays. In addition to display device design and development, his career has also encompassed displays specifications and standards, applications and marketing.

Mr. Tannas has been awarded for patents, a NASA Disclosure, and NASA Certificate of Recognition. He has published numerous articles as well as a book entitled *Flat-Panel Displays and CRT's*.

**B. JAPANESE ORGANIZATIONS AND FACILITIES VISITED**

Sony Corporation  
Tokyo

Nippon Hoso Kyokai  
Tokyo

High Definition TV Engineering  
Corporation  
Tokyo

Matsushita Electric Industries  
Company, Ltd.  
Osaka

Engineering Center  
Kashiwa

Mitsubishi Electric Consumer  
Electronics Research Center  
Kyoto

The Museum of Fine Arts  
Gifu

Hi-Vision Promotion Center (HVC)  
Kawasaki

Broadcasting Bureau  
Tokyo

Ikegami Tsushinki, Ltd.  
Tokyo

NTT Yokosuka R&D Center  
Kanagawa

Hitachi Consumer Products  
Research Center  
Yokohama

Hitachi Central Research Laboratory  
Tokyo

Toshiba Corporation  
Tokyo

NHK Laboratories  
Tokyo

HDTEC  
Tokyo

Sharp Research Center  
Kashiwa

Ministry of International Trade  
and Industry (MITI)  
Tokyo

Ministry of Posts and  
Telecommunications  
Tokyo

NTT  
Yokosuka

### C. GLOSSARY OF HDTV TERMS<sup>1</sup>

1050/59.94, 1125/60, 1250/50, 1375/50, etc. The number of **scan lines** followed by the **field rate** of various **HDTV** system proposals.

**Active line.** The lines used to carry the actual picture. For example, 483 out of the 525 lines in NTSC television are active lines. The remaining lines are used for synchronizing and auxiliary signals.

**ACTV (advanced compatible television).** A joint effort of the David Sarnoff Research Laboratories and NBC television for a three-phase **transmission** system. The first phase, ACTV-E, is the entry-level system, which provides a wide **aspect ratio** and enhanced picture in a single six-megahertz **channel**. The second phase, ACTV-I, provides improved vertical and horizontal **resolution** in a single six-megahertz channel. And the third phase, ACTV-II, is a two-channel system with performance similar to the **MUSE 1125/60** proposal.

**AEA (American Electronics Association).** A Trade association of U.S. electronics companies whose purpose is to provide a healthy business environment for the industry and to strengthen its position in world markets.

**Alternative media.** The delivery of electronic television programs by means other than traditional ground-based broadcasting, such as cable, fiber-optics, **DBS**, **VCR**, and video disk.

**ANSI (American National Standards Institute).** A national standard-setting organization that sets voluntary standards for the U.S. It also forms the U.S. positions and delegations for **IEC** and **ISO** international voluntary standards meetings.

**Artifact.** An audio or video impairment or defect that can be produced during the processing or **transmission** of a signal.

**Aspect ratio.** The ratio of picture width to picture height. The ratio for conventional TV is 4:3, whereas the proposed ratio for **HDTV** is 16:9, closer to the aspect ratio of 35mm movies.

**ATSC (Advanced Television Standards Committee).** An organization formed and funded by U.S. companies, including subsidiaries of foreign companies, who have an interest in developing voluntary standards for advanced television systems. They propose systems to the U.S. government for

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<sup>1</sup> From: Ampex Corp. brochure, "Everyone's Talking About HDTV, But What are the Facts?"  
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consideration as mandatory standards. The charter members of this committee are members of **JCIC**. **ATTC (Advanced Television Test Center)**. A center formed and funded by U.S. broadcaster to test advanced TV systems. Its major work is to test proponent systems for consideration by the FCC Advisory Committee on Advanced Television Service as the U.S. terrestrial system for **ATV**.

**ATV (advanced television)**. A generic term used to refer to all **transmission** proposals offering improved performance.

**Bandwidth**. The frequency, measured in megahertz, required to contain a television signal or other electronic signal.

**Bandwidth compression**. The method of reducing the bandwidth required to transmit an electronic signal.

**Bit rate**. The data rate (number of bits of data transferred per second) in a digital signal. The digital equivalent of **bandwidth**.

**Bit-rate reduction**. A method of reducing or compressing the data rate of a digital signal, whereby data is removed with the least possible picture impairment.

**Broadcast television**. TV programming delivered according to government-authorized standards (**NTSC**, **PAL**, **SECAM**, etc.) normally by licensed terrestrial broadcast or cable re-broadcast.

**BTA (Broadcast Technology Association)**. An organization of Japanese broadcasters and broadcast equipment manufacturers who have an interest in developing voluntary standards for Japanese advanced television systems. (Similar to the **ATSC**.)

**Cable Labs**. A lab set up by the **NCTA** to test cable systems, including those for **ATV**.

**CATS (Center for Advanced Television Studies)**. A consortium of U.S. television broadcasters and manufacturers formed to fund **ATV** research to encourage students to enter this field following graduation.

**CCIR (Comite Consultatif International des Radiocommunications)**. An organization under the **ITU** which studies technical questions and issues recommendations for international radio matter. The members are the telecommunications administrations of **ITU**-member countries and recognized private operating agencies, including broadcasting organizations.

**CD (compact disc)**. A method of digital storage and reproduction of music.

**Channel**. The amount of **spectrum** (radio frequency) required for a television signal.

**Chrominance**. The color part of a television signal. (See also **luminance** and **composite**.)

**Clear-Vision.** The Japanese name for their **EDTV** system.

**Cochannel interference.** Distortion or interference on one TV channel caused by simultaneous broadcasts on an adjacent channel.

**Compatibility.** The ability of present TV sets to receive new types of signals but display them in the old way-in much the same way that black-and-white TVs could receive, but not display, color (signals when color TV first came out. (Actually, the **NTSC** color system was not fully compatible with the black-and-white because adding color caused some degradation to the black-and-white picture.)

**Component.** A television system in which the **luminance** and two or three color signals (**chrominance**) are kept separate from one another.

**Composite.** A color television signal containing both **luminance** and encoded **chrominance** information.

**Cross-color.** An unwanted color signal, or **artifact** in the **composite**, that results when a luminance signal has the same frequency range of a signal in the encoded color **subcarrier**.

**DBS (direct broadcast satellite).** A method of delivering a TV signal or other electronic signal directly to the home via a stationary-orbit satellite.

**Decode.** To convert from an encoded or combined multiple-part signal to its individual parts.

**Delivery standard.** See transmission standard.

**EBU (European Broadcasting Union).** A union of European broadcast organizations whose purpose is, among other things, to develop standards for the exchange of program material among its members. Several U.S. broadcast organizations belong as non-voting associate members.

**EDTV (extended-or enhanced-definition television).** A form of **ATV** that provides better resolution than conventional TV but not as good as **HDTV**. Also referred to as **IDTV** (improved-definition television.)

**EIA (Electronic Industries Association).** A trade association of U.S. companies, including subsidiaries of foreign companies, in the electronics field--primarily consumer electronics such as TV receivers.

**EIAJ (Electronic Industries Association of Japan).** A trade association of Japanese companies in the electronics field--primarily consumer electronics such as TV receivers.

**Emission.** The broadcast or transmission of a television signal or other radio frequency signal.

**Encode.** To convert the components of a color signal into a single combined television signal such as **NTSC**, **PAL** OR **SECAM**.

**ETV (enhanced television).** An improvement of the standard **NTSC**, **PAL** or **SECAM** signal usually accomplished in the TV set with internal processing.

**Eureka EU95.** Established by the Commission of the European Communities (CED) to encourage collaboration on **ATV**, Eureka EU95 now has 19 participating countries. The Eureka EU95 project is aimed at defining a world standard for HDTV in the 1990s.

**FCC (Federal Communications Commission).** The U.S. government agency dealing with communications.

**FCC Advisory Committee on Advanced Television Service.** The industry committee set up by the **FCC** to advise them on advanced television systems such as **EDTV** and **HDTV**.

**Field.** The alternate lines that compose one-half of a **frame**, or a complete television picture. (See **interlaced scan**.)

**Field rate.** The rate at which each **field** of a TV picture is changed or refreshed. The **NTSC** field rate is 59.94 cycles per second. The **PAL/SECAM** field rate is 50 cycles per second.

**Frame.** One complete television picture or scan.

**Frame rate.** The rate at which the complete TV picture is changed or refreshed. The **NTSC** frame rate is 29.97 cycles per second. The **PAL/SECAM** frame rate is 25 cycles per second.

**Frame store.** The storage of one complete TV picture or **frame**.

**Fukinuki hole.** A gap in the energy **spectrum** of a TV signal used for imbedded information to improve **resolution**. Named for the Japanese engineer who made the discovery.

**HD-MAC (high-definition multiplexed analog component).** An **HDTV** television system intended for **DBS** delivery in Europe.

**HD-NTSC.** A wide-screen, 900-line **ATV** system proposed by the Del Rey Group.

**HDTV (high-definition television).** A television system with twice the vertical **resolution** and twice the horizontal resolution of conventional TV. It also features a wide-screen display and high-fidelity stereo sound of **CD** quality.

**Hi-Vision.** The Japanese name for their **HDTV** system.

**House Subcommittee on Telecommunications, Consumer Protection and Finance.** The House of Representatives subcommittee that deals with telecommunications and other areas.

**IDTV (Improved-definition television).** See EDTV.

**IEC (International Electrotechnical Commission).** Worldwide, private and non-governmental scientific organization whose aim is the international voluntary standardization of electric and electronic products, including those used for recording audio and video signals.

**IEEE (Institute of Electrical and Electronics Engineers).** A technical society of electrical and electronics engineers whose mission for the TV segment includes defining methods of measurement.

**Interlaced scan.** The method of interleaving TV fields so that the complete picture can be displayed, without flicker, using a lower total bandwidth. (See also **progressive scan**.)

**ISO (International Organization for Standardization).** Worldwide, private and non-governmental scientific organization for international voluntary standardization of mechanical devices, including such diverse things as motion-picture film and screw threads.

**ITU (International Telecommunication Union).** An intergovernmental organization, with 164 member countries, whose aim is to develop regulations and voluntary recommendations, provide coordination of telecommunication development, and foster technical assistance for developing countries. The **CCIR** is one of the organizations under the **ITU** umbrella.

**JCIC (Joint Committee for Inter-Society Coordination).** A group composed of representatives from **EIA**, **IEEE**, **NAB**, **NCTA** and **SMPTE** whose goal is to define jurisdiction in areas of work and standardization between the organizations.

**Line rate.** The number of scan lines per second (the number of scan lines per frame times the frame rate.)

**Line-rate conversion.** Converting from one TV line rate or system to another.

**Luminance.** The monochrome, or black-and-white, part of a TV signal. (See also **chrominance** and **composite**.)

**MAC (multiplexed analog components).** A method that uses studio component video signals but multiplexes them in time to fit them into a single channel for **DBS**.

**MPAA (Motion Picture Association of America).** A trade association for the motion picture industry, which includes member companies, leading U.S. producers and distributors of films for theaters, television and home video in the U.S. and around the world.

**Multipath distortion.** Picture distortion caused when a TV antenna receives a reflected or unwanted signal in addition to the direct signal from the broadcaster. (Also called ghosting.)

**MUSE (multiple sub-Nyquist sampling encoding).** An HDTV delivery method, a form of **bandwidth** compression developed by NHK specifically for DBS. (See also **MAC**.)

**NAB (National Association of Broadcasters).** A trade association for U.S. radio and television broadcasters.

**NANBA (North American National Broadcasters Association).** An association of broadcasters from North America to discuss issues of mutual interest. Similar to the various broadcast unions of the world, such as the **EBU**.

**NCTA (National Cable Television Association).** A trade association for cable television companies.

**NHK (Nippon Hoso Kyokai).** The national radio and television broadcaster for Japan. Operates an important lab in Tokyo for radio and

television research and funded some of the earliest work in HDTV.

**NTIA (National Telecommunication and Information Administration).** A U.S. government agency, under the Department of Commerce, responsible for national telecommunications and related activity.

**NTSC (National Television Systems Committee).** The industry group that defined the current FCC-approved color television system.

**PAL (phase alternating line).** The type of TV system used in most European countries, the People's Republic of China, and Australia.

**Pixel.** The smallest resolvable element of a TV signal.

**Post-production.** The process of editing and embellishing tape or film footage into the final viewable product. Electronic post-production is that which uses only electronic means to arrive at the final product.

**Presentation.** The process of showing the finished film or TV program.

**Production.** The process of creating the rough and unedited film or videotape from a script.

**Production equipment.** The equipment used in the **production** and **post-production** of TV programming-devices such as cameras, recorders, switches, and titling generators.

**Production standard.** A set of technical specifications used to create the images for original programming. This studio standard usually uses higher performance criteria than needed for transmission. (See **delivery standard**.)

**Progressive scan.** A TV picture that does not use **interlaced fields** and is thereby complete in one **scan**. Each field has an identical line structure and can be electronically produced from an interlaced source.

**Raster.** The periodic electronic structure made up of **scan lines** used to create a TV **frame**.

**Resolution.** A measure of the finest image element that can be seen in a TV picture. (See also **sharpness**.)

**Resolving power.** The ability to reproduce the finest detail of an image.

**RGB.** The primary additive television colors -- red, green, and blue.

**Scanning.** See **interface scan** and **progressive scan**.

**Scanning lines.** The horizontal lines, caused by electron beam traces, that make up a TV picture.

**SECAM (sequential encoded color amplitude modulation.)** The TV system used in France, the Soviet Union, and other Eurasian and African countries.

**Sharpness.** The visual perception of **resolution**.

**SMPTE (Society of Motion Picture and Television Engineers).** A technical society which develops voluntary recommended practices and standards in motion picture engineering and television production engineering. Most SMPTE standards become **ANSI** standards.

**Spatial.** Pertaining to two-dimensional space, as in a single television **frame**. (See also **temporal**.)

**Spectrum.** The continuous range of radio frequencies such as those allocated to **UHF TV channels** or FM radio.

**Standards conversion.** To change from one TV format such as **NTSC** to another such as **PAL**.

**Subcarrier.** A frequency embedded in the **spectrum** of a signal to carry additional or separate information.

**Super NTSC.** An improved and compatible **NTSC** system developed by Faroudja Laboratories.

**Taboo channels.** FCC-designated TV channels, which are adjacent to active channels within a given geographic area and would cause **cochannel interference** if they were used.

**Temporal.** The sequence of time. Spatio-temporal in TV terms would be the passage of frames through time. (See also **spatial**.)

**Terrestrial broadcast.** TV signals delivered by ground-based **transmitter** to an audience within a specified geographic area.

**Transcoding.** Converting from one **encoded** format to another, as in transcoding from **NTSC** to **PAL**.

**Transmitter.** The device used to deliver an electronic signal.

**Transmission.** Delivery of an electronic signal by **emission** or cable.

**Transmission standard.** A set of agreed-upon rules for transmitting signals to the home. (Not to be confused with **production standards**, which usually have a higher **bandwidth**.)

**UHF (ultra high frequency).** The TV frequency band of 470 to 590 megahertz. (See also **VHF**.)

**Vertical blanking interval.** The period of time required for the electron **scan** to return from the bottom to the top of a TV display.

**VHF (very high frequency).** The television frequency band of 54 to 216 megahertz. (See also **UHF**.)

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